Bacteria Total Maximum Daily Load Development for Beaver Creek

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CHAPTER 1: EXECUTIVE SUMMARY

1.1. Background

The Beaver Creek watershed (VAV-B18R, 10,205 acres) is located in Rockingham County, Virginia, to the west of Harrisonburg. Beaver Creek is a tributary of the North River (USGS Hydrologic Unit Code 02070005), which in turn, is a tributary of the South Fork of the Shenandoah River. The Shenandoah River flows into the Potomac River. The Potomac River discharges into the Chesapeake Bay. A major contributor to flow in Beaver Creek is a spring located about 4.4 stream miles upstream of the watershed outlet.

1.2. Bacteria Impairment

1.2.1. Background

Water quality samples collected in Beaver Creek over a period of 10 years (1994 -2004) indicated that 27% of the samples violated the instantaneous water quality standard for fecal coliform. The instantaneous freshwater water quality standard for fecal coliform under which the Beaver Creek impairment was listed specified that fecal coliform concentration in the stream water should not exceed 1,000 colony forming units (cfu) per 100 mL. Due to the frequency of water quality violations, Beaver Creek was placed on Virginia's 2002 303(d) list of impaired water bodies for fecal coliform. Beaver Creek has been assessed as not supporting the Clean Water Act's Swimming Use Support Goal for the 2002 305(b) report. As listed in the fact sheet, the Beaver Creek impairment starts at the headwaters of the stream and continues downstream to its confluence with the Briery Branch. This includes a total of 5.57 stream miles.

In order to remedy the fecal coliform water quality impairment, a Total Maximum Daily Load (TMDL) has been developed, taking into account all sources of bacteria and a margin of safety (MOS). The TMDL was developed for the new water quality standard for bacteria, which states that the calendar-month geometric mean concentration of *E. coli* shall not exceed 126 cfu/100 mL, and that no single sample can exceed a concentration of 235 cfu/100mL. A glossary of terms used in the development of this TMDL is listed in Appendix A.

1.2.2. Sources of Bacteria

There are seven small (1,000 gpd) sources permitted to discharge bacteria in the Beaver Creek watershed; however, the majority of the bacteria load originates from nonpoint sources. The nonpoint sources of bacteria are mainly agricultural and include land-applied animal waste and manure deposited on pastures by livestock. A significant bacteria load comes from cattle and wildlife directly depositing feces in streams. Wildlife also contribute to bacteria loadings on all land uses, in accordance with the habitat range for each species. Non-agricultural nonpoint sources of bacteria loadings include straight pipes, failing septic systems, and pet waste. The amounts of bacteria produced in different locations (e.g., confinement, pasture, forest) were estimated on a monthly basis to account for seasonal variability in wildlife behavior and livestock production and practices. Livestock management and production factors, such as the fraction of time cattle spend in confinement, pastures, or streams; the amount of manure storage; and spreading schedules for manure application, were considered on a monthly basis.

1.2.3. Modeling

The Hydrological Simulation Program – FORTRAN (HSPF) (Bicknell et al., 2001) was used to simulate the fate and transport of fecal coliform bacteria in the Beaver Creek watershed. To identify localized sources of fecal coliform within the watershed, Beaver Creek watershed was divided into 11 sub-watersheds, based on homogeneity of land use and stream network connectivity.

The hydrology component of HSPF was not calibrated as a continuous observed flow record does not exist for the watershed. Hydrologic parameters were either estimated from existing digital maps and sources or copied from the nearby Muddy Creek watershed. The Department of Environmental Quality measured flow on five dates during the TMDL development period; these data were compared to simulated flows.

The water quality component of the HSPF model was calibrated for Beaver Creek using 5 years (January 1999 – December 2003) of fecal coliform data collected in the watershed. Inputs to the model included fecal coliform loadings on land and in the stream. A comparison of simulated and observed fecal coliform loadings in the stream indicated that the model adequately simulated the fate and transport of fecal coliform bacteria.

1.2.4. Margin of Safety

A margin of safety (MOS) was included to account for any uncertainty in the TMDL development process. There are several different ways that the MOS could be incorporated into the TMDL (USEPA, 1991). For Beaver Creek, the MOS was implicitly incorporated into the TMDL by conservatively estimating several factors affecting bacteria loadings, such as animal numbers, bacteria production rates, and contributions to streams.

1.2.5. Existing Conditions

Contributions from various sources in the Beaver Creek watershed were represented in HSPF to establish the existing conditions for a representative 3-year period that included both low and high-flow conditions. Meteorological data from 1989-1991 were paired with bacterial loading and land use data for existing conditions to establish this baseline scenario. Results of the calibrated HSPF model predict that an estimated that 70% of the *E. coli* in the mean daily *E. coli* concentration at the watershed outlet currently comes from upland contributions of cattle, wildlife, humans, and pets; 16% from cattle directly depositing in the streams; 9% comes from wildlife directly depositing in the stream; 4% from straight pipes directly discharging to the stream; and 1% from interflow and groundwater contributions. Simulated bacteria concentrations exceeded the calendar-month geometric mean water quality standard 33% of the time at the watershed outlet.

1.2.6. TMDL Allocations and Stage 1 Implementation

Monthly bacteria loadings to different land use categories were calculated for each sub-watershed in each watershed for input into HSPF based on amounts of bacteria produced in different locations. Bacteria content of stored waste was adjusted to account for die-off during storage prior to land application. Similarly, bacteria die-off on land was taken into account, as was the reduction in bacteria available for surface wash-off due to incorporation following waste application on cropland. Direct seasonal bacteria loadings to streams by cattle were calculated for pastures adjacent to streams. Bacteria loadings to streams and land by wildlife were estimated for several species. Bacteria loadings to land from failing septic systems were estimated based on number and age of houses. Bacteria contribution from pet waste was also considered.

The major spring in sub-watershed BVR-04 acts as a source of dilution for the bacteria concentrations. However, the primary DEQ monitoring station, 1BBVR003.60, was located on Waggys Creek above its confluence with the Beaver Creek spring. In order to ensure standards compliance at both the ambient monitoring station and the watershed outlet, the Beaver Creek watershed was divided into two segments: Waggys Creek in the upstream area and Lower Beaver Creek in the downstream area. This resulted in two sets of allocation scenarios; more reductions were recommended for the Waggys Creek watershed due to the lack of dilution effects of the spring.

When developing a bacteria TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria applied to the land surface. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in Table 1.1 and Table 1.2 in the next section indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions for from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

For the TMDL allocation scenarios, a target of zero violations of both the instantaneous and geometric mean water quality standards was used. For the Stage 1 implementation scenario, a target of zero reductions in wildlife and 10% violation of the instantaneous standard was used.

1.2.7. Allocation Scenarios

After calibrating to the existing water quality conditions, different source reduction scenarios were evaluated to identify implementable scenarios that meet both the calendar-month geometric mean *E. coli* criterion (126 cfu/100 mL) and the single sample maximum *E. coli* criterion (235 cfu/100 mL) with zero violations. These scenarios were conducted using meteorological data from 1989-1991 to represent a variety of high and low flow conditions. The dates in the allocation graphs correspond to these meteorological years; however, the bacteria loadings used in modeling correspond to anticipated future conditions for the Beaver Creek watershed. The reductions required in the Waggys Creek watershed are presented in Table 1.1; reductions required in the Lower Beaver Creek watershed are presented in Table 1.2.

Table 1.1. Allocation scenarios for the Waggys Creek watershed.

Scenario Number	% Violation of *E. coli* standard		Required Fecal Coliform Loading Reductions to Meet the *E coli* Standards,%					
	Geomean	Single Sample	Cattle DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
Existing Conditions	100%	56%	0	0	0	0	0	0
W1	33%	5%	100	100	100	0	100	100
W2	28%	0%	100	100	100	20	100	100
W3	0%	0%	100	100	100	50	100	100

Table 1.2. Allocation scenarios for the Lower Beaver Creek watershed.

Scenario Number	% Violation of *E. coli* standard		Required Fecal Coliform Loading Reductions to Meet the *E coli* Standards,%					
	Geomean	Single Sample	Cattle DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
Existing Conditions	33%	11%	0	0	0	0	0	0
B1	0.0%	8%	50	0	0	0	100	0
B2	0.0%	1%	50	30	95	0	100	0
B3	0.0%	0.1%	100	20	100	0	100	0
B4	0.0%	0.0%	100	50	99	0	100	0
B5	0.0%	0.0%	0	30	100	0	100	0

Due to the low flows commonly encountered in Waggys Creek, elimination of all anthropogenic sources (scenario W1) still resulted in 33% and 5% violations of the geometric mean and instantaneous standards, respectively. The direct deposit from wildlife in the low flow volumes of Waggys Creek caused these violations. Therefore, scenario W3 was the only successful allocation scenario for Waggys Creek.

The reductions in Table 1.2 are applied only to the Lower Beaver Creek watershed; scenario W3 reductions were applied to the Waggys Creek portion of Beaver Creek for these scenarios. In scenario B1 for Lower Beaver Creek, straight pipes were eliminated and large reductions (50%) were taken from direct deposition of cattle in the streams. This had a significant effect, eliminating the violations of the geometric mean standard and reducing the violation of the instantaneous standard by 3%. Reducing contributions from cropland and pasture (scenario B2) dropped the instantaneous violation rate another 7%. As can be seen from scenario B3, a small increase in loading reductions from pasture more than compensates for a larger decrease in loading reductions from cropland. Thus, the successful allocation scenarios (B4 and B5) require higher reductions from pasture, and lower reductions from other sources. The lack of a requirement for direct deposit reductions from cattle in Scenario B5 is due to the dilution effect of the spring – this reduces the contributions of direct deposit loadings to standards violations. Many cattle have already been fenced from the stream in Lower Beaver Creek. Because there is always a substantial flow in Lower Beaver Creek, the bacteria load from the remaining cattle do not create a high enough concentration to violate the water quality standards under baseflow conditions. However, the high concentrations of bacteria transported to the stream from pasture areas during runoff events do cause standards violations. Because the loading from cattle direct deposit has a small effect on the in-stream concentration in Lower Beaver Creek during higher flow runoff periods when the standard is violated, a 100% cattle direct deposit reduction is required in scenario B4 in order to compensate for a less than 100% load reduction from pasture areas.

Scenarios B4 and B5 both meet both *E. coli* standards and would be acceptable targets for implementation. Because Scenario B5 is less restrictive than B4, the calculated TMDL loads and associated graphs and tables in this report are for Scenario B5. This scenario requires no reductions from cattle stream access, wildlife, or residential areas in the Lower Beaver Creek watershed. The concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 1.2 for the TMDL allocation (Scenario B5), along with the standards. During implementation planning, the implementation plan steering committee could choose either successful scenario upon notification to EPA.

The required load reductions for the TMDL allocation are listed for wet weather nonpoint sources in Table 1.3 and for direct nonpoint sources in Table 1.4. The instantaneous and calendar-month geometric mean fecal coliform concentrations resulting from Scenario B5 are presented graphically in Figure 1.1 and Figure 1.2.

Table 1.3. Annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the successful TMDL allocation scenario (Scenario W3/B5).

Land use Category	Watershed Fragment	Existing Conditions		Allocation Scenario	
		Existing conditions load ($\times 10^{12}$ cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load ($\times 10^{12}$ cfu/yr)	Percent reduction from existing load
Cropland	Waggys	23	<1%	0	100%
	Lower Beaver	133	1%	93	30%
Pasture	Waggys	7,451	44%	0	100%
	Lower Beaver	9,092	54%	0	100%
Residential[a]	Waggys	81	<1%	0	100%
	Lower Beaver	121	1%	121	0%
Forest	Waggys	58	<1%	58	0%
	Lower Beaver	9	<1%	9	0%
Total	Waggys	7,613	45%	58	99%
	Lower Beaver	9,355	55%	224	98%
	All	16,968	100%	282	98%

[a] Includes loads applied to both High and Low Density Residential and Farmstead

Table 1.4. Annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for the successful TMDL allocation scenario (Scenario W3/B5).

Source	Watershed Fragment	Existing Condition		Allocation Scenario	
		Existing conditions load ($\times 10^{12}$ cfu/yr)	Percent of total direct deposited load from direct nonpoint sources	TMDL direct nonpoint source allocation load ($\times 10^{12}$ cfu/yr)	Percent reduction
Cattle in streams	Waggys	22	32%	0	100%
	Lower Beaver	11	16%	11	0%
Straight Pipes	Waggys	3	4%	0	100%
	Lower Beaver	19	27%	0	100%
Wildlife in Streams	Waggys	9	13%	4	50%
	Lower Beaver	6	8%	6	0%
Total	Waggys	34	49%	4	87%
	Lower Beaver	35	51%	17	53%
	All	69	100%	21	70%

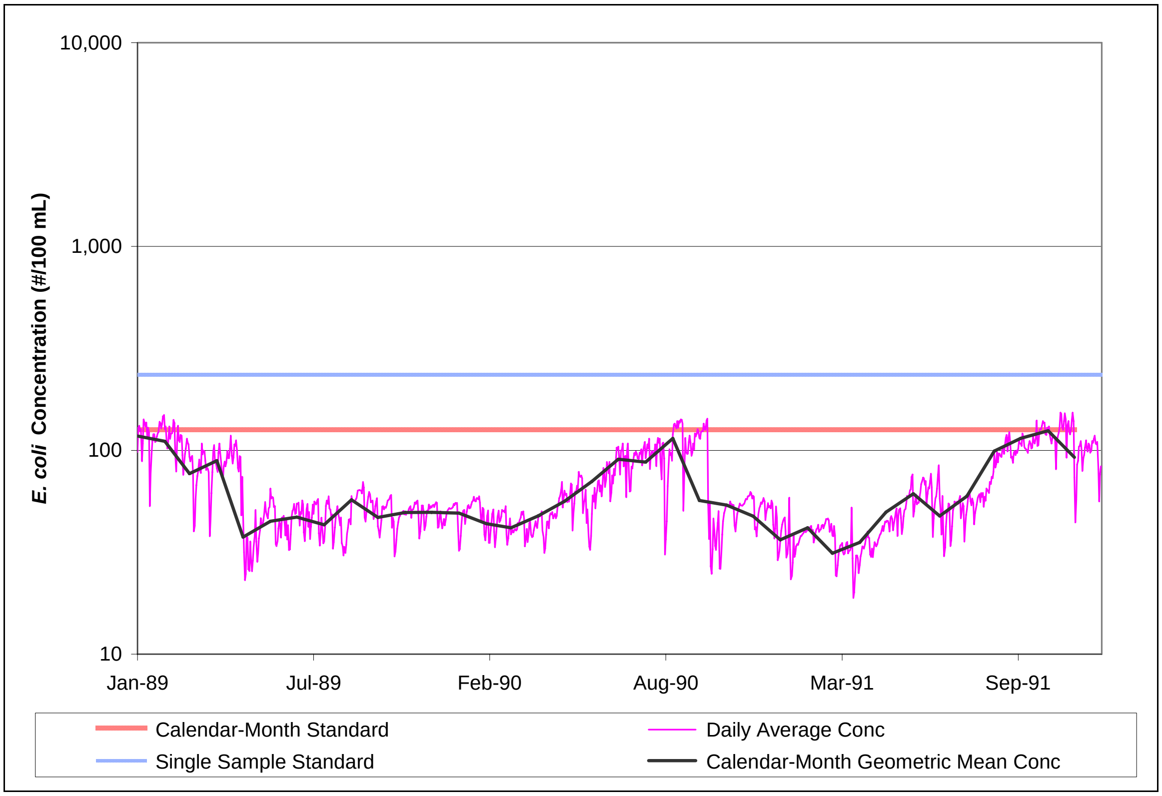

Figure 1.1. Calendar-month geometric mean standard, single sample standard, and successful *E. coli* TMDL allocation (Allocation Scenario W3) for Waggys Creek watershed (location of monitoring station).

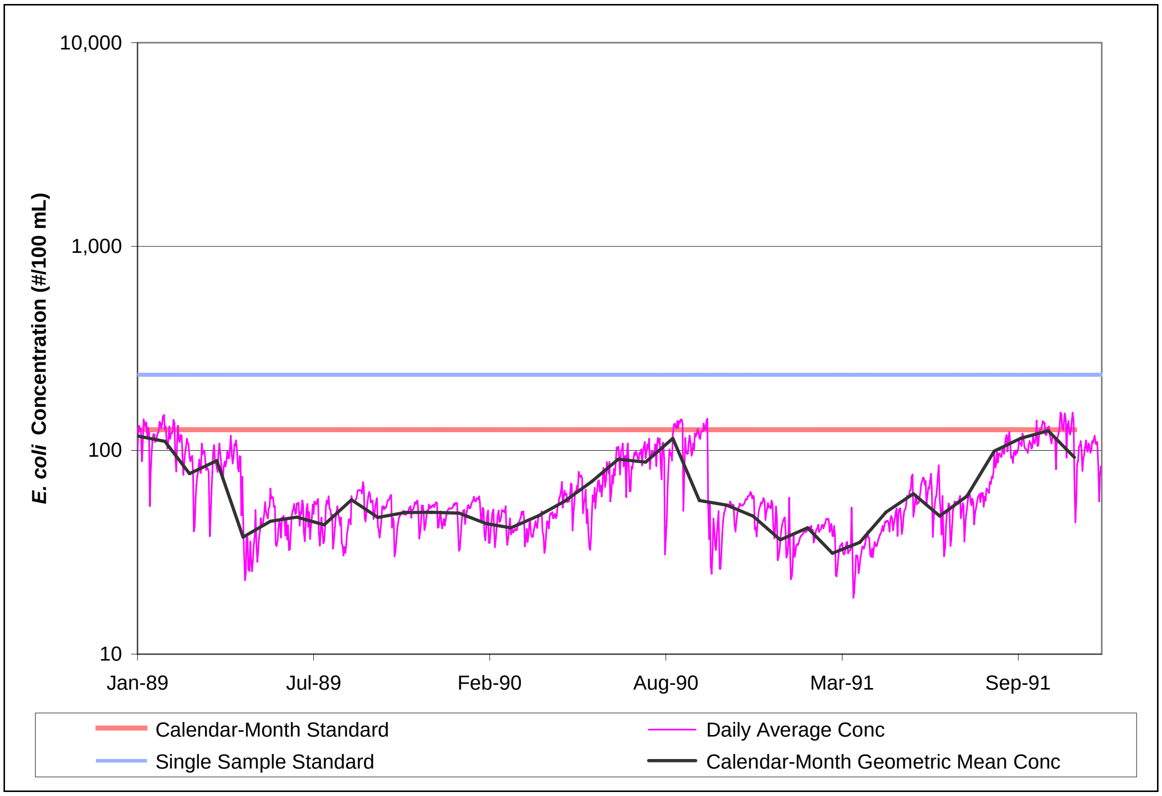

Figure 1.2. Calendar-month geometric mean standard, single sample standard, and successful *E. coli* TMDL allocation (Allocation Scenario B5) for Lower Beaver Creek watershed (outlet of main watershed).

Equation [1.1] was used to calculate the TMDL allocation shown in Table 1.5.

$$TMDL = \Sigma WLA + \Sigma LA + MOS \qquad [1.1]$$

where:

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

There are seven small point sources discharging at or below their permit requirements; therefore, the proposed scenario requires load reductions only for nonpoint sources of fecal coliform. The TMDL was determined as the average annual *E. coli* load at the watershed outlet for the chosen allocation scenario. The WLA was obtained by taking the product of the permitted point source's *E. coli* discharge concentration and allowable annual discharge. The LA is then determined as the TMDL-WLA.

Table 1.5. Annual *E. coli* loadings (cfu/year) at the watershed outlet used for the Beaver Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS[a]	TMDL
E. coli	1.22×10^{10} *(Σ 7 general permits=1.22×10^{10})*	$1{,}567 \times 10^{10}$	--	$1{,}568 \times 10^{10}$

[a] Implicit MOS

In the Waggys Creek watershed, the proposed scenario requires a 100% reduction in bacteria loads from all land uses except forest, a 100% reduction from straight pipes and livestock direct deposits to streams, and a 50% reduction from wildlife direct deposit to streams. Reductions from the Lower Beaver Creek watershed were not as severe and required a 100% reduction in straight pipes and from pasture loadings and a 30% reduction in loadings from cropland.

1.2.8. Stage 1 Implementation

Alternative scenarios were evaluated to establish a first stage for the implementation of the TMDL. The implementation of such a transitional scenario, or Stage 1 implementation, will allow for an evaluation of the effectiveness of management practices and accuracy of model assumptions through data collection. Stage 1 implementation was developed for a maximum of 10% violation rate of the single sample *E. coli* water quality standard (235 cfu/100 mL), based on daily averages of simulated concentrations. In addition, the Stage 1 scenario was designed without reductions from wildlife.

As with the allocation scenarios, the stage 1 implementation scenarios for the Beaver Creek watershed are different for Waggys Creek and Lower Beaver Creek. Two scenarios were evaluated for Waggys Creek (Table 1.6): the first requires a 90% reduction in direct loading by cattle in-stream, a 95% reduction in loadings from pasture, and a 100% reduction in straight pipes. The second requires an 81% reduction in direct loading by cattle in-stream, a 99% reduction in loadings from pasture, and a 100% reduction in straight pipes. Both are options for the stakeholders during the implementation process to come. With the reductions in loadings coming from Waggys Creek for these scenarios, Lower Beaver Creek required only a 100% reduction in straight pipes to meet the stage

1 implementation criteria (10% violation of the instantaneous standard) at the watershed outlet (Table 1.7).

Table 1.6. Allocation scenarios for Stage 1 TMDL implementation for Waggys Creek watershed.

Scenario Number	Single Sample Standard % Violation	% Reduction Required					
		Cattle DD	Cropland	Pasture	Wildlife DD	Straight Pipes	All Residential PLS
W1	9	100	0	95	0	100	0
W2	13	75	0	99	0	100	0
W3	10	90	0	95	0	100	0
W4	10	81	0	99	0	100	0

Table 1.7. Allocation scenarios for Stage 1 TMDL implementation for Lower Beaver Creek watershed.

Scenario Number	Single Sample % Violation	% Reduction Required					
		Cattle DD	Cropland	Pasture	Wildlife DD	Straight Pipes	All Residential PLS
B1 (based on W3)	9	0	0	0	0	100	0
B2 (based on W4)	9	0	0	0	0	100	0

1.3. Reasonable Assurance of Implementation

1.3.1. Follow-Up Monitoring

The Department of Environmental Quality (VADEQ) will continue monitoring Beaver Creek (1BBVR003.60) in accordance with its ambient and biological monitoring programs to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards.

1.3.2. Regulatory Framework

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in attainment of water quality standards. This report represents the culmination of that effort for the bacteria impairment on Beaver Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and to monitor stream water quality to determine if water quality standards are being attained.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

1.3.3. Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual (VADCR and VADEQ, 2003) contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

1.4. Public Participation

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. In October of 2004, members of the Virginia Tech TMDL development group traveled to Rockingham County to become acquainted with the watershed. During that trip, the Virginia Tech personnel spoke with various stakeholders. In addition, Virginia Tech personnel visited watershed residents and contacted others via telephone to acquire their input. Two public meetings were held. The first public meeting was organized on September 22, 2004 at the Ottobine Elementary school in Dayton, Virginia to inform the stakeholders of TMDL development process. The draft TMDL report was discussed at the final public meeting held on July 12, 2005, also at the Ottobine Elementary School. In addition to these public meetings, a group of interested stakeholders was gathered on two occasions to comment on the TMDL process. During the first local steering committee meeting on October 25, 2004 at the DEQ office in Harrisonburg, the committee members provided feedback on and refinement of the human and animal numbers used in modeling. During the second meeting on

February 22, 2005, also located at the DEQ office, the committee members provided feedback on the water quality calibration.

CHAPTER 2: INTRODUCTION

2.1. Background

2.1.1. TMDL Definition and Regulatory Information

Section 303(d) of the Federal Clean Water Act and the U.S. Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to identify water bodies that violate state water quality standards and to develop Total Maximum Daily Loads (TMDLs) for such water bodies. A TMDL reflects the total pollutant loading a water body can receive and still meet water quality standards. A TMDL establishes the maximum allowable pollutant loading from both point and nonpoint sources for a water body, allocates the load among the pollutant contributors, and provides a framework for taking actions to restore water quality.

2.1.2. Impairment Listing

Beaver Creek is listed as impaired on Virginia's 2002 Section 303(d) Total Maximum Daily Load Priority List and Report (VADEQ, 2002) due to water quality violations of the bacteria standard. The Virginia Department of Environmental Quality (VADEQ) has delineated the impairment on Beaver Creek on a stream length of 5.57 miles. As described in Virginia's 2002 Section 303(d) report, the impaired stream segment begins at the Beaver Creek headwaters and continues downstream to its confluence with Briery Branch. Beaver Creek is targeted for TMDL development and completion by 2014.

2.1.3. Watershed Location and Description

A part of the Shenandoah River basin, the Beaver Creek watershed (Watershed ID VAV-B18R) is located west of Harrisonburg in Rockingham County, Virginia, (Figure 2.1). The watershed is 10,205 acres in size. Beaver Creek is mainly a forested watershed (about 61%). All but one percent of the remaining 39% is agricultural land with the remaining one percent having various degrees of rural development. Beaver Creek flows southeast, merges with Briery Branch, and eventually discharges into the North River (USGS Hydrologic Unit

Code 02070005). North River is a tributary of the South Fork of the Shenandoah River, which flows into the Potomac River; the Potomac River discharges into the Chesapeake Bay.

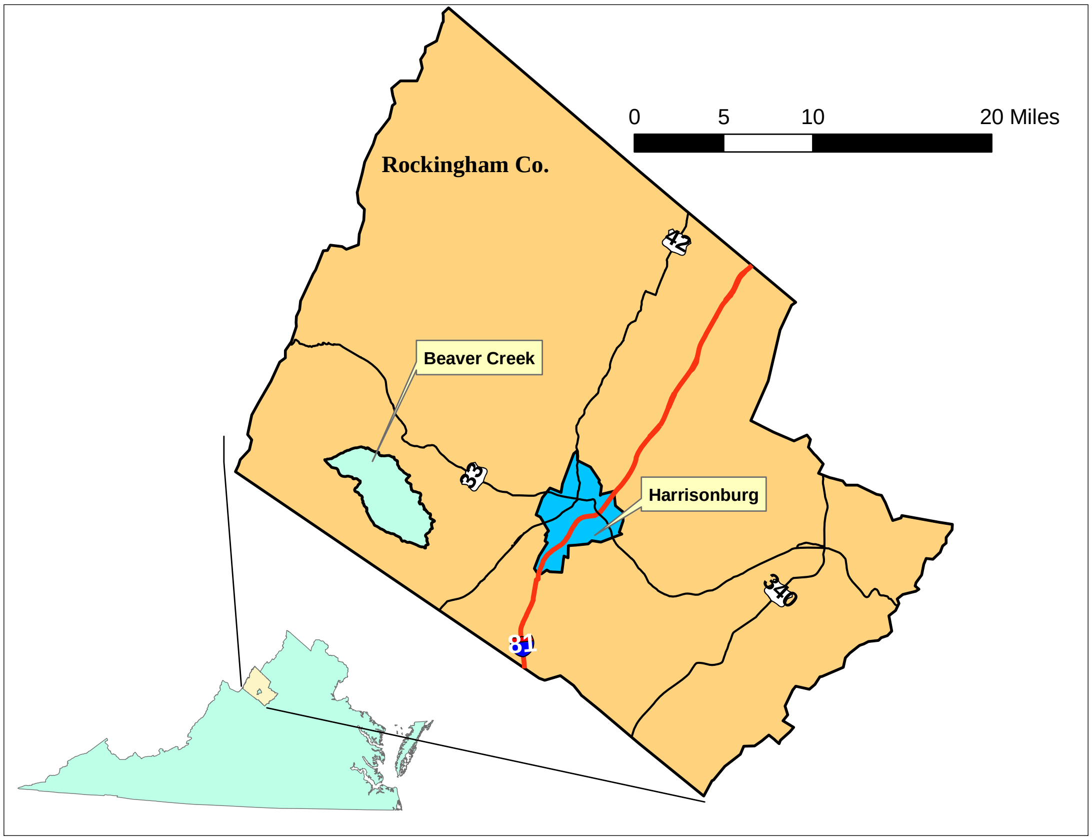

Figure 2.1. Location of the Beaver Creek watershed.

2.1.4. Pollutants of Concern

Pollution from both point and nonpoint sources can lead to fecal coliform bacteria contamination of water bodies. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals; consequently, fecal waste of warm-blooded animals contains fecal coliform. Even though most fecal coliform are not pathogenic, their presence in water indicates contamination by fecal material. Because fecal material may contain pathogenic organisms, water bodies with fecal coliform bacteria are potential sources of pathogenic organisms. For contact recreational activities such as boating and swimming, health risks increase with increasing fecal coliform counts. If the fecal coliform concentration in a water body exceeds state water quality standards, the water body is listed for violation of the state bacteria standard for contact recreational uses. As discussed in Section 2.2.2, Virginia has adopted an *Escherichia coli* (*E. coli*) water quality standard. The concentration of *E. coli* (a subset of the fecal coliform group) in water is considered to be a better indicator of pathogenic exposure than the concentration of the entire fecal coliform group in the water body.

2.2. Designated Uses and Applicable Water Quality Standards

2.2.1. Designation of Uses (9 VAC 25-260-10)

> "A. All State waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish." SWCB, 2004.

Beaver Creek does not support the recreational (swimming) designated use due to violations of the bacteria criteria.

2.2.2. Bacteria Standard (9 VAC 25-260-170)

EPA has recommended that all states adopt an *E. coli* or enterococci standard for fresh water and enterococci criteria for marine waters, because there is a stronger correlation between the concentration of these organisms (*E. coli* and enterococci) and the incidence of gastrointestinal illness than there is with fecal coliform. *E. coli* and enterococci are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals and are subsets of the fecal coliform and fecal streptococcus groups, respectively. In line with this recommendation, Virginia adopted and published revised bacteria criteria on June 17, 2002. The revised criteria became effective on January 15, 2003. As of that date, the *E. coli* standard described below applies to all freshwater streams in Virginia. Additionally, prior to June 30, 2008, the interim fecal coliform standard must be applied at any sampling station that has fewer than 12 samples of *E. coli*.

For a non-shellfish water body to be in compliance with Virginia's revised bacteria standards (as published in the Virginia Register Volume 18, Issue 20) the following criteria shall apply to protect primary contact recreational uses (SWCB, 2004):

Interim Fecal Coliform Standard:

> Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 mL of water for two or more samples over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 mL of water.

Escherichia coli **Standard:**

> *E. coli* bacteria concentrations for freshwater shall not exceed a geometric mean of 126 counts per 100 mL for two or more samples taken during any calendar month and shall not exceed a single sample maximum of 235 cfu/100mL.

During any assessment period, if more than 10% of a station's samples exceed the applicable standard, the stream segment associated with that station is classified as impaired and a TMDL must be developed and implemented to bring the station into compliance with the water quality standard. The original impairment to Beaver Creek was based on exceedences of an earlier fecal coliform standard that included a numeric single sample maximum limit of 1,000 cfu/100 mL. The bacteria TMDL for these impaired segments will be developed to meet the *E. coli* standard. As recommended by VADEQ, the modeling will be conducted with fecal coliform inputs, and then a translator equation will be used to convert the output to *E. coli*.

CHAPTER 3: WATERSHED CHARACTERIZATION

3.1. Water Resources

The Beaver Creek Watershed was subdivided into 11 sub-watersheds for fecal coliform modeling purposes as discussed in Section 5.2. Union Springs Run drains the upper, wooded part of the watershed and ends at a dam with a drainage area of 3,351 acres. All streams in the Beaver Creek watershed are intermittent except Beaver Creek itself. Beaver Creek begins at a spring with an average flow rate of 24.6 cfs; this is the primary contributor to flow in the watershed. There is no flow monitoring station on Beaver Creek and therefore, no historic record of flow is available. The flow rate at several points in the watershed was monitored on five occasions to provide a reference for comparison of modeled flows. Close attention has to be paid to the naming convention of streams in Beaver Creek watershed as there is discrepancy between what the local residents of the watershed recognize as stream names and what is listed on various digital databases and on the USGS DRG. Figure 3.1 and Figure 3.2 show the previously recognized naming scheme by DEQ and the local recognition of stream names, respectively. The latter is the naming scheme that will be used in this report. Aquifers in this watershed are overlain by limestone, carbonate strata with interbedded limestone, dolomite, and calcareous shale (SCS, 1982; Smith and Ellison, 1985).

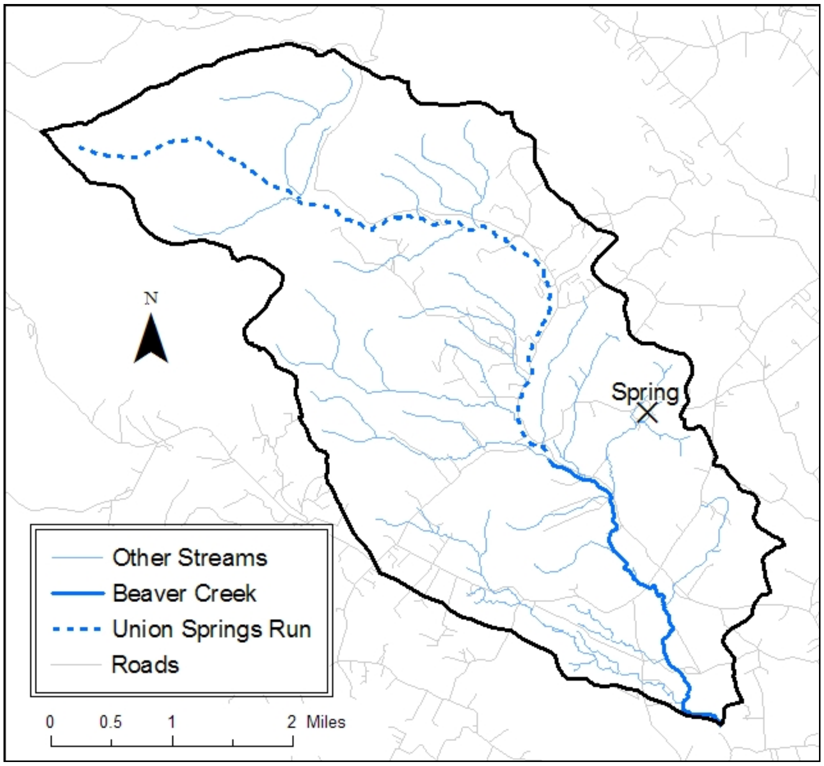

Figure 3.1. Beaver Creek Streams as Previously Recognized by DEQ.

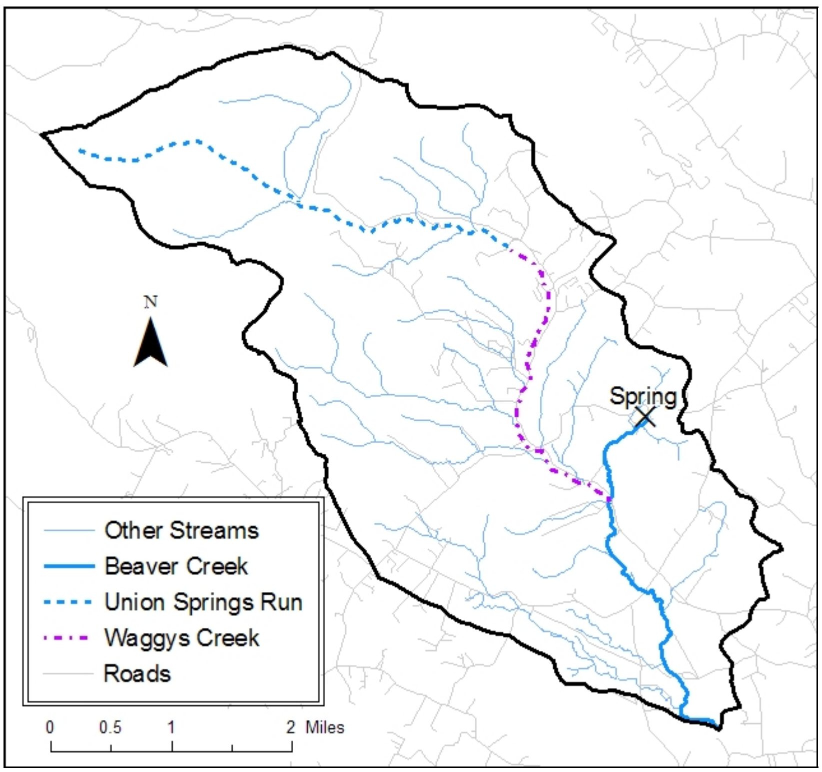

Figure 3.2. Local Recognition of Beaver Creek Streams (and the way they will be referenced in this report)

3.2. Selection of Sub-watersheds

To account for the spatial distribution of fecal coliform sources, the watershed was divided into 11 sub-watersheds as shown in Figure 3.3. The impaired section of Beaver Creek (VAV-B18R) begins at the headwaters and runs to the confluence with Briery Branch. The stream network was delineated based on the blue line stream network from USGS topographic maps with each sub-watershed having at least one stream segment. Because loadings of bacteria are believed to be associated with land use activities and the degree of development in the watershed, sub-watersheds were chosen based on uniformity of land use. Other factors influencing the delineation of sub-watersheds include the stream network layout and monitoring station locations. The junctions of stream segments are useful locations to break sub-watersheds to preserve the contiguity of the stream network. In this light, small sub-watersheds were added in areas where multiple stream segments meet, such as sub-watersheds BVR-1, BVR-6, and BVR-7. A third factor that was taken into consideration in delineating the sub-watersheds was the existence of monitoring stations. It is preferable to have a sub-watershed outlet at monitoring station locations in order to calibrate the model chosen for this study (to be discussed in Chapter 5).

In most bacteria TMDLs, allocation scenarios are developed for the entire watershed. However, in order to account for the effects of the spring on Beaver Creek, the 11 sub-watersheds were grouped into two areas when considering necessary reductions for the allocation scenarios (see Section 6.1.2.b). In generating reductions for the allocation scenarios, the Beaver Creek watershed was considered in two parts: the Waggys Creek area of the watershed (sub-watersheds 5-11 upstream of the spring) and the Lower Beaver Creek area of the watershed (sub-watersheds 1-4) (Figure 3.3).

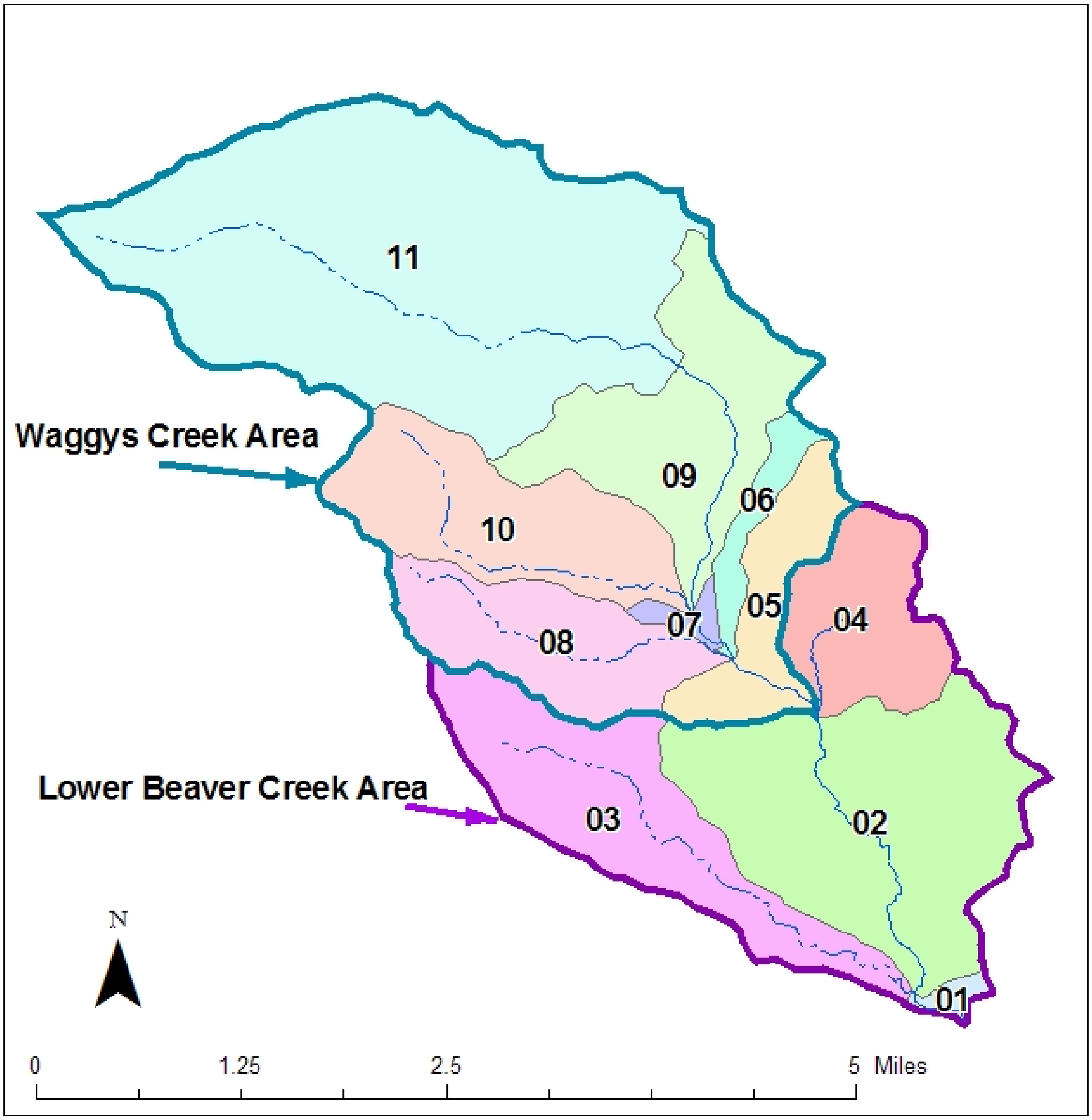

Figure 3.3. Beaver Creek Sub-Watersheds.

3.3. Ecoregion

The Beaver Creek watershed is located in the Central Appalachian Ridges and Valleys Level III Ecoregion. It is located primarily in the Northern Limestone/Dolomite Valleys Level IV Ecoregion. The ridges tend to be forested, while limestone valleys are composed of rich agricultural land (USEPA, 2002). The Northern Limestone/Dolomite Valleys Level IV ecoregion has fertile land and is primarily agricultural. Steeper areas have scattered forests composed mainly of oak trees.

3.4. Soils and Geology

Three soil groups are found in Beaver Creek watershed. The Lehew-Dekalb-Calvin association is primarily in the upper part of the watershed and is characterized by moderately deep, sloping to very steep, well-drained soils that have loamy subsoil. The second association is Frederick-Lodi-Rock to the east of Waggys Creek and west of Beaver Creek below the confluence with Waggys Creek. This association is characterized by deep, gently sloping to steep soils that are well-drained with clayey subsoil and areas of rock outcrop. The third major association is Monongahela-Unison-Cotaco to the west of Waggys Creek and west of Beaver Creek below the confluence with Waggys Creek. This soil series is characterized by level to moderately steep slopes, deep, well drained to moderately well drained soils with clayey or loamy sub-soils (SCS, 1982).

3.5. Climate

The climate of the watershed is characterized based on the meteorological observations acquired at “nearby” weather stations including Dale Enterprise (Virginia), Lynchburg Airport (Virginia), and Elkins Airport (West Virginia). The long-term record summary (8/1/1948-3/31/2004) available for the nearby Dale Enterprise station at the Southeast Regional Climate Center shows average annual precipitation to be 35.57 in., with 59% of the precipitation occurring during the cropping season (May-October). Average annual snowfall at Dale Enterprise is 24.6 in., with the highest snowfall occurring during February. Average annual daily temperature is 53.3°F. The highest average daily temperature of 73.7°F occurs in July while the lowest average daily temperature of 32.3°F occurs in January (SERCC, 2004).

3.6. Land Use

From the 1992 National Land Cover Dataset (NLCD) (USGS, 2005), land uses in Beaver Creek were grouped into five major categories based on similarities in hydrologic features and waste application/production practices (Table 3.1). Using these groupings, forest is the main land use category in the

Beaver Creek watershed, comprising 60.6% of the total watershed area. The lower part of the watershed is primarily pasture (34.6%) with cropland occupying about 3.7% of the watershed area. Residential and rural developments cover 1.1% of the total area. These six categories were assigned pervious and impervious percentages for use in the watershed model. Land uses for the Beaver Creek watershed are presented in Table 3.2 and graphically in Figure 3.4.

Table 3.1. Consolidation of NLCD land use for the Beaver Creek watershed.

TMDL Land Use Categories	Pervious/Impervious[a] (Percentage)	NLCD Land Use Categories (Class No.)
Cropland	Pervious (100%)	Row Crops (82)
Hay[b]	Pervious (100%)	Pasture/Hay (81)
Pasture[b]	Pervious (100%)	Pasture/Hay (81)
Low Density Residential	Pervious (70%) Impervious (30%)	Low Intensity Residential (21) Transitional (33)
High Density Residential	Pervious (50%) Impervious (50%)	Commercial/Industrial/Transport (23)
Forest	Pervious (100%)	Open Water (11) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43) Woody Wetlands (91) Emergent Herbaceous Wetlands (92)

[a] Percent perviousness/imperviousness information was used in modeling (described in Section 5.4)

[b] Hay and Pasture areas were broken out based on the NPS assessment for the area

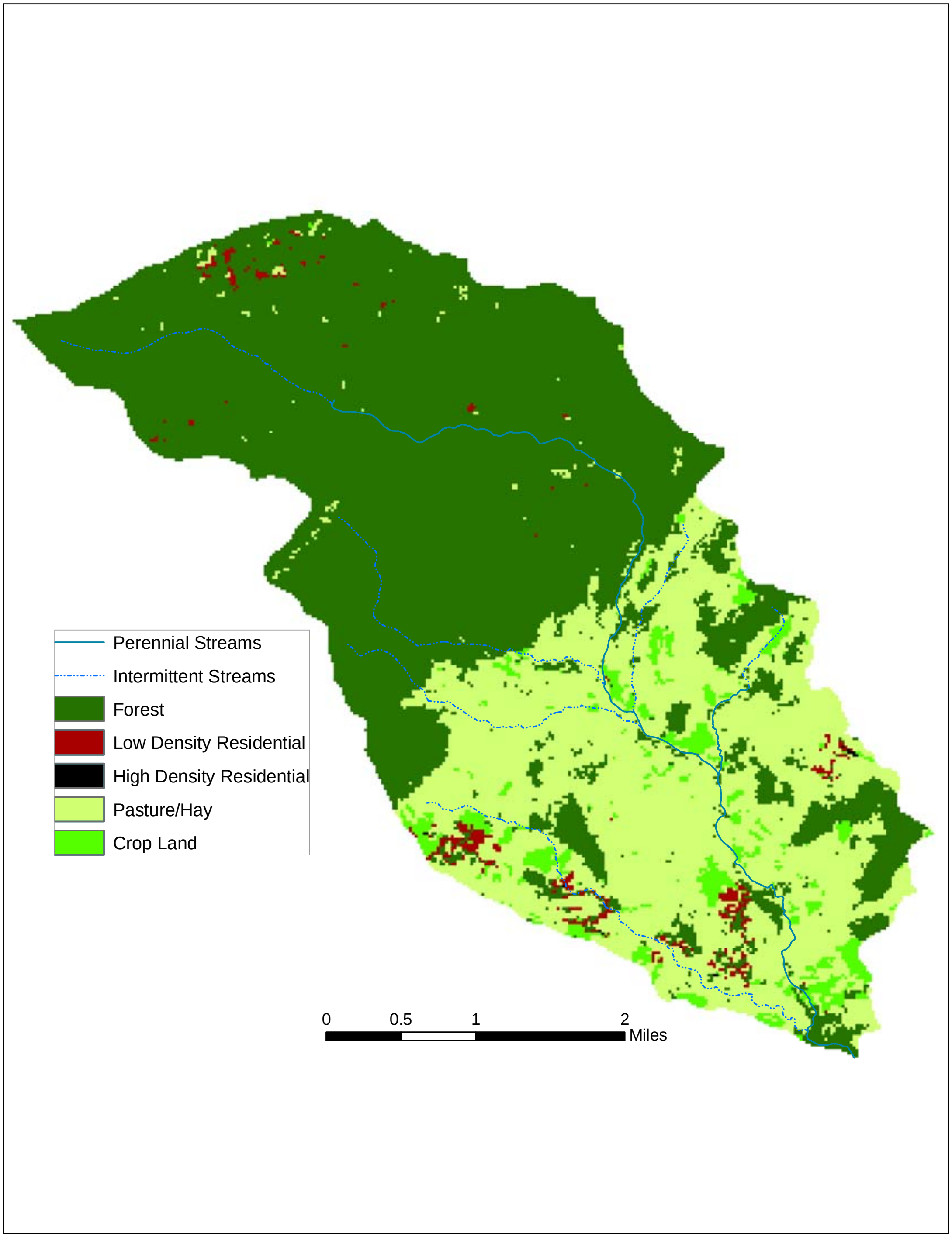

Figure 3.4. Beaver Creek Watershed Land Use.

Table 3.2. Land use distribution in the Beaver Creek watershed (acres).

Land use	Sub-watersheds[a]											
	BVR-01	BVR-02	BVR-03	BVR-04	BVR-05	BVR-06	BVR-07	BVR-08	BVR-09	BVR-10	BVR-11	Total
Forest	30.9	326.5	235.3	154.8	87.4	27.1	1.1	270.4	937.4	812.2	3,297	6,180.1
Cropland	0.4	136.1	117	37.6	45.4	11.1	13.3	8.7	4.7	6	1.3	381.6
Hay	7.5	438.8	251.5	150.8	122.7	49.7	18.5	163.8	37.4	39.6	10.4	1,290.7
Pasture	13	760.1	435.7	261.1	212.5	86	32	283.7	64.9	68.5	18.1	2,235.6
Low Density Residential	0	30	54.9	3.1	0	0	0.2	0	0.9	0	24	113.1
High Density Residential	0	1.6	1.8	0	0	0	0	0	0	0	0	3.4
Total	51.8	1,693.1	1,096.2	607.4	468	173.9	65.1	726.6	1,045.3	926.3	3,350.8	**10,204.5**

[a]Sub-watersheds 1-4 constitute the Lower Beaver Creek watershed; sub-watersheds 5-11 constitute the Waggys Creek watershed

3.7. Stream Flow Data

There are no continuous flow monitoring stations on Beaver Creek. Thus, a complete hydrologic calibration could not be conducted. The model parameters needed to simulate the watershed hydrology were gleaned from two sources. Many of the calibrated hydrologic parameters from the nearby Muddy Creek watershed were used in the Beaver Creek model. The remaining hydrologic parameters, those that have a direct relation to physical characteristics of the watershed (e.g., land slope), were obtained from digital maps of the Beaver Creek watershed as detailed in Chapter 5.

DEQ staff collected flow data on five dates at four locations in the watershed (as discussed in Section 5.6.1); although these data were insufficient to conduct a hydrologic calibration, they were compared to simulated flows to ensure that model predictions were reasonable.

3.8. Water Quality Data

The Virginia DEQ (VADEQ) monitored Beaver Creek chemical and bacterial water quality on and off from September 1994 to the present. The main monitoring station, where most of the record exists, is 1BBVR003.60, located on Waggys Creek at the bridge of US Route 731. A total of 33 samples were taken from September 1994 to January 2005. One sample per year was taken from 1994 to 1997 after which sampling stopped for almost two years. In general, from August 1999 to June 2003, a sample was taken every other month. Sampling resumed in October 2004 and has occurred monthly since that time.

The Virginia Department of Conservation and Recreation has assessed the Beaver Creek watershed as having a potential for nonpoint source pollution from agricultural and wildlife sources. Of the 29 water quality samples collected by VADEQ from September 1994 to June 2003 at station 1BBVR003.60, 9 samples exceeded the single sample maximum fecal coliform standard of 1,000 cfu/100 mL. Consequently, Beaver Creek was assessed as not supporting the Clean Water Act's Swimming Use Support Goal for the 2004 305(b) report and was included in the 2004 303(d) list (VADEQ, 2004). Figure 3.5 shows the timeline and fecal coliform concentrations. During the period used for calibration (January 1, 1999 to June 30, 2003), a total of 25 samples were taken, seven of which violated the old 1,000 cfu/100mL instantaneous standard, and 12 of which violated the new 400 cfu/100mL instantaneous standard.

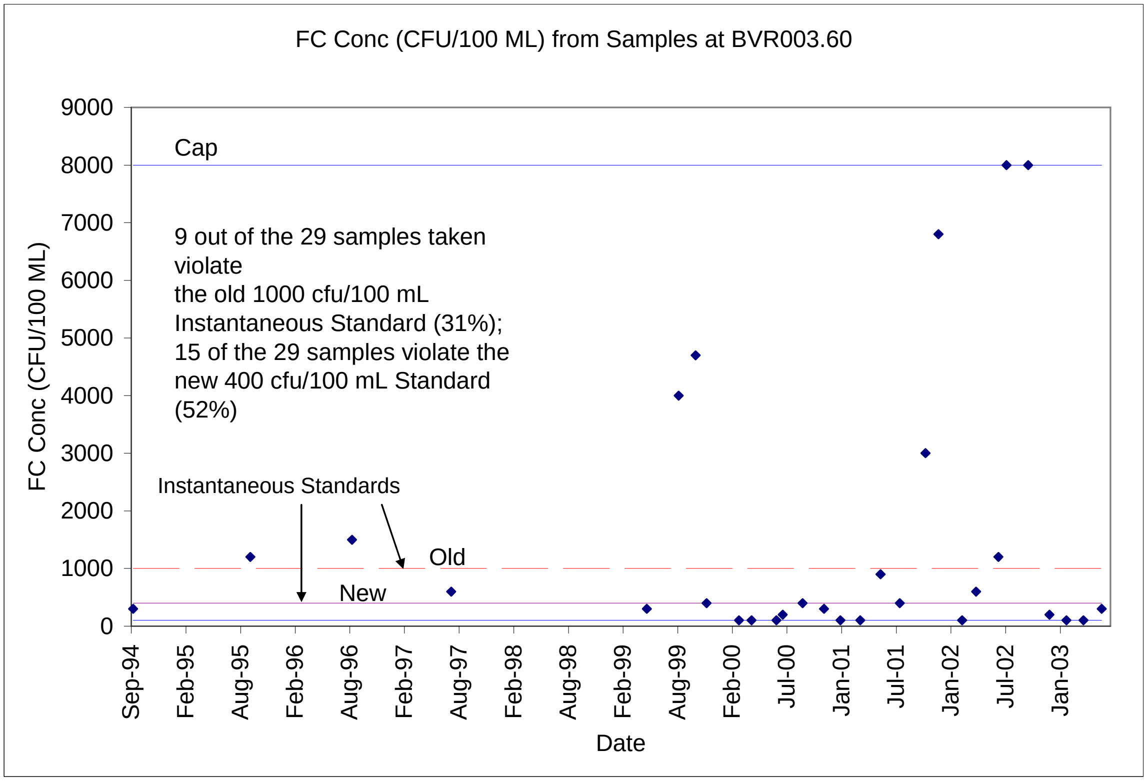

Figure 3.5. Time series of fecal coliform concentration in Beaver Creek.

The Membrane Filter Method (MFM) was used for the analysis of fecal coliform in water samples for Beaver Creek. The samples analyzed with this method had caps of 8,000 cfu/100 mL.

Seasonality of fecal coliform concentration in the streams was evaluated by plotting the mean monthly fecal coliform concentration values (Figure 3.6). Mean monthly fecal coliform concentration was determined as the average of one to four values for each month; the number of values varied according to the available number of samples for each month in the 1994 to 2003 period of record.

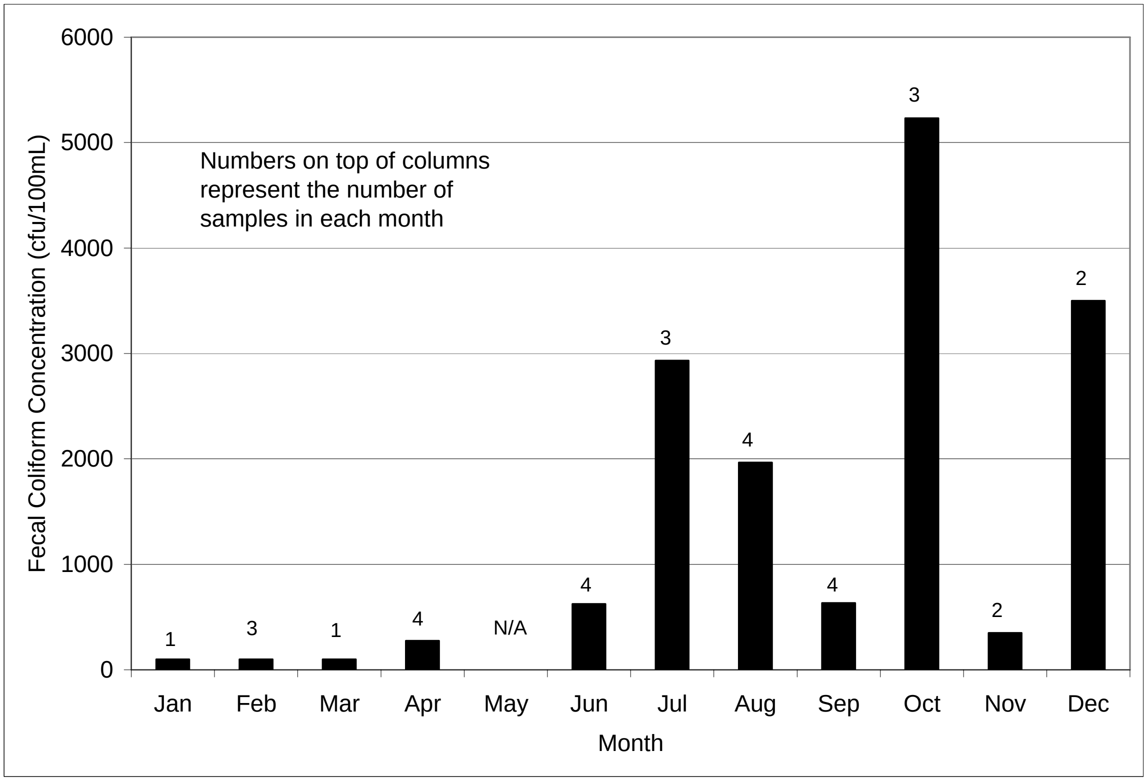

Figure 3.6. Impact of seasonality on fecal coliform concentrations in Beaver Creek.

The data indicate seasonal variability with higher in-stream fecal coliform concentrations occurring during the summer and fall months and lower concentrations typically occurring during the winter and spring months, with the exception of December. During summer (June – August), the average fecal coliform concentration was 1,720 cfu/100mL compared with 240 cfu/100mL during spring (March – May). The highest seasonal concentration was 2,287 cfu/100mL and occurred during fall (September – November). It should be noted that due to the cap imposed on the fecal coliform count (8,000 cfu/100 mL), the actual counts could be much higher when fecal coliform levels are equal to these maximum levels, increasing the averages shown in Figure 3.6.

CHAPTER 4: SOURCE ASSESSMENT OF FECAL COLIFORM

Fecal coliform sources in the Beaver Creek watershed were assessed using information from the following sources: VADEQ, VADCR, Virginia Department of Game and Inland Fisheries (VADGIF), Virginia Department of Agricultural and Consumer Services (VDACS), Virginia Cooperative Extension (VCE), NRCS, public participation, watershed reconnaissance and monitoring, published information, and professional judgment. Point sources and potential nonpoint sources of fecal coliform are described in detail in the following sections and summarized in Table 4.1 and Table 4.2.

Table 4.1. Potential fecal coliform sources and daily fecal coliform production by source in Beaver Creek watershed.

Potential Source	Population in Watershed	Fecal coliform produced ($\times 10^6$ cfu/head-day)
Humans	984	1,950[a]
Dairy cattle		
Milk and dry cows	790	20,200[b]
Heifers [c]	216	9,200[d]
Beef cattle	802	20,000
Pets	343	450[e]
Poultry[f]		
Chicken Broilers	350,600; 470,600	136[g]
Turkey Pullets	66,000; 66,000	28[h]
Turkeys	260,800; 134,800	93[g]
Ewes	46	12,000[g]
Horses	47	420[g]
Deer	480	350
Raccoons	183	50
Muskrats	37	25[i]
Beavers	18	0.2
Wild Turkeys	102	93[g]
Ducks[j]	35, 54	800
Geese[j]	46, 63	2,400

[a] Source: Geldreich (1978)
[b] Based on data presented by Metcalf and Eddy (1979) and ASAE (1998)
[c] Includes calves
[d] Based on weight ratio of heifer to milk cow weights and fecal coliform produced by milk cow
[e] Source: Weiskel *et al*. (1996)
[f] Population given as calibration period; allocation period
[g] Source: ASAE (1998)
[h] Based on bacteria concentration in turkey manure (ASAE(1998)) and relative manure production by pullets and turkeys (local data)
[i] Source: Yagow (2001)
[j] population given as summer, winter population

Point sources of fecal coliform bacteria in the Beaver Creek watershed include private residences that fall under general permits. Virginia issues Virginia Pollutant Discharge Elimination System (VPDES) permits for point sources of pollution. In Virginia, point sources that treat human waste are required to maintain a fecal coliform concentration of 200 cfu/100 mL or less in their effluent. There were 7 general permits in Beaver Creek watershed, as detailed in Table 4.2. In allocation scenarios for bacteria, the entire allowable point source discharge concentration of 200 cfu/100 mL was used.

Table 4.2. General Permits discharging into streams of the Beaver Creek watershed.

Permit Number	Facility Name	City	Sub-Watershed	Design Flow (gpd)	Permitted FC Conc. (cfu/100 mL)	FC Load (cfu/year)
VAG401004	Homeowner	Dayton	BVR-9	1000	200	$2.76*10^9$
VAG401143	Homeowner	Dayton	BVR-11	1000	200	$2.76*10^9$
VAG401144	Homeowner	Dayton	BVR-9	1000	200	$2.76*10^9$
VAG401478	Homeowner	Dayton	BVR-9	1000	200	$2.76*10^9$
VAG401599	Homeowner	Ottobine	BVR-9	1000	200	$2.76*10^9$
VAG401679	Homeowner	Dayton	BVR-9	1000	200	$2.76*10^9$
VAG408022	Homeowner	Dayton	BVR-2	1000	200	$2.76*10^9$

4.1. Humans and Pets

The Beaver Creek watershed has an estimated population of 984 people (343 households at an average of 2.87 people per household; actual people per household varies by sub-watershed). Fecal coliform from humans can be transported to streams from failing septic systems or via straight pipes discharging directly into streams.

4.1.1. Failing Septic Systems

Septic system failure can be evidenced by the rise of effluent to the soil surface. Surface runoff can transport the effluent containing fecal coliform to receiving waters. There were no sewered areas in the Beaver Creek watershed. Unsewered households were located using E-911 digital data obtained from the GIS Coordinator for Rockingham County Community Development in November

2004. Each unsewered household was classified into one of three age categories (pre-1967, 1967-1984, and post-1984) based on the Briery Branch USGS 7.5-min. topographic map, which was initially created using 1967 photographs and was photo-revised in 1984. It was assumed that septic system failure rates for houses in the pre-1967, 1967-1984, and post-1984 age categories were 40, 20, and 3%, respectively (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Estimates of these failure rates were also supported by the Holmans Creek Watershed Study (a watershed located in Rockingham County), which found that over 30% of all septic systems checked in the watershed were either failing or not functioning at all (SAIC, 2001).

Daily total fecal coliform load to the land from a failing septic system in a particular sub-watershed was determined by multiplying the average occupancy rate for that sub-watershed (occupancy rate ranged from 1 to 3 persons per household (Census Bureau, 2000)) by the per capita fecal coliform production rate of 1.95×10^9 cfu/day (Geldreich, 1978). Hence, the total fecal coliform loading to the land from a single failing septic system in a sub-watershed with an occupancy rate of 1 persons/household was 1.95×10^9 cfu/day. Transport of some portion of the fecal coliform to a stream by runoff may occur. The number of failing septic systems in the watershed is given in Table 4.3.

4.1.2. Straight Pipes

Of the houses located within 150 ft of streams, in the pre-1967 and 1967-1984 age categories, 10%, and 2%, respectively, were estimated to have straight pipes (R.B. Reneau, personal communication, 3 December 1999, Blacksburg, Va.). Based on these criteria, it was estimated that three Beaver Creek sub-watersheds had one straight pipe each: sub-watersheds 3, 8, and 9.

4.1.3. Pets

Assuming one pet per household, there are 343 pets in Beaver Creek watershed. A dog produces fecal coliform at a rate of 0.45×10^9 cfu/day (Weiskel et al., 1996); this was assumed to be representative of a ‘unit pet’ – one dog or several cats. The pet population distribution among the sub-watersheds is listed in Table 4.3. Pet waste is generated in the rural residential areas. Surface runoff can transport bacteria in pet waste from residential areas to the stream.

Table 4.3. Estimated number of unsewered houses by age category, number of failing septic systems, and pet population in Beaver Creek watershed.

Sub-watershed[a]	Unsewered houses in each age category (no.)				Failing septic systems (no.)	Pet population[b]
	Straight Pipes	Pre-1967	1967-1984	Post-1984		
BVR-01	0	0	0	0	0	0
BVR-02	0	37	20	34	20	91
BVR-03	1	38	18	35	20	92
BVR-04	0	6	2	4	3	12
BVR-05	0	8	0	4	32	12
BVR-06	0	2	3	8	2	13
BVR-07	0	1	0	0	0	1
BVR-08	1	7	0	4	3	12
BVR-09	1	34	21	41	19	97
BVR-10	0	5	2	0	2	7
BVR-11	0	1	0	5	1	6
Total	3	139	66	135	73	343

[a] Sub-watersheds 1-4 consitute the lower Beaver Creek watershed; sub-watersheds 5-11 consitute the Waggys Creek watershed

[b] Assumed an average of one pet per household.

4.2. Cattle

Fecal coliform in cattle waste can be directly excreted to the stream, or it can be transported to the stream by surface runoff from animal waste deposited on pastures or applied to crop, pasture, and hay land.

4.2.1. Distribution of Dairy and Beef Cattle in the Beaver Creek Watershed

There are 9 dairy farms in the watershed, based on reconnaissance and information from VDACS. From communication with local dairy farmers, it was determined that there are 674 milk cows, 116 dry cows, and 216 heifers in the watershed (Table 4.1). The dairy cattle population was distributed among the sub-watersheds based on the location of the dairy farms. Table 4.4 shows the number of dairy operations for each sub-watershed.

Table 4.4. Distribution of dairy cattle, dairy operations and beef cattle among Beaver Creek sub-watersheds.

Sub-watershed[a]	Dairy cattle	No. of dairy operations	Beef cattle
BVR-01	0	0	6
BVR-02	419	5	180
BVR-03	182	2	135
BVR-04	0	0	90
BVR-05	0	0	151
BVR-06	0	0	1
BVR-07	316	1	16
BVR-08	0	0	145
BVR-09	0	0	33
BVR-10	89	1	35
BVR-11	0	0	10
Total	1,006	9	802

[a] Sub-watersheds 1-4 consitute the lower Beaver Creek watershed; sub-watersheds 5-11 consitute the Waggys Creek watershed

Beef cattle in the watershed included cow/calf and feeder operations. There were no permitted beef CAFOs in the watershed. The beef cattle population (802) in the watershed was estimated based on feedback obtained from local stakeholders in the watershed during the Local Steering Committee meeting. The total number of beef cows varied throughout the year due to the presence or absence of calves and their weights relative to the adult cattle.

Beef and dairy cattle spend varying amounts of time in confinement, loafing lots, streams, and pasture depending on the time of year and type of cattle (e.g., milk cow versus heifer). Accordingly, the proportion of fecal coliform deposited in any given land area varies throughout the year. Based on discussions with NRCS, VADCR, VCE, and local producers, the following assumptions and procedures were used to estimate the distribution of cattle (and thus their manure) among different land use types and in the stream.

a) Cows are confined according to the schedule given in Table 4.5.

b) When dairy and beef cattle are not confined, they are on pasture.

c) Beef cattle on pastures that are contiguous to unfenced streams (123.4 acres, Table 4.6) have stream access. This number was obtained through analysis of GIS land use and stream information. Stream access reported by dairy farmers during data collection was used for the dairy cows.

d) Cows with stream access spend varying amounts of time in the stream during different seasons (Table 4.5). Cows spend more time in the stream during the three summer months to protect their hooves from hornflies, among other reasons.

e) Thirty percent of cows in and around streams directly deposit fecal coliform into the stream. The remaining 70% of the manure is deposited on pastures.

Table 4.5. Time spent by cattle in confinement and in the stream.

Month	Time spent in confinement (%)		Time spent in the stream (hours/day)[a]
	Milk cows	Dry cows, heifers, and beef cattle	
January	75%	40%	0.50
February	75%	40%	0.50
March	40%	0%	0.75
April	30%	0%	1.00
May	30%	0%	1.50
June	30%	0%	3.50
July	30%	0%	3.50
August	30%	0%	3.50
September	30%	0%	1.50
October	30%	0%	1.00
November	40%	0%	0.75
December	75%	40%	0.50

[a] Time spent in and around the stream by cows that have stream access.

A sample calculation for determining the distribution of cattle to different land use types and to the stream in sub-watershed BVR-02 is shown in Appendix B. The resulting numbers of cattle in each land use type as well as in the stream for all sub-watersheds are given in Table 4.7 for dairy cattle and in Table 4.8 for beef cattle.

Table 4.6. Pasture acreages contiguous to stream.

Sub-watershed[a]	Acres	%[b]
BVR-01	0.8	11%
BVR-02	52.7	12%
BVR-03	0.0	0%
BVR-04	19.6	13%
BVR-05	20.5	12%
BVR-06	0.05	4%
BVR-07	5.7	31%
BVR-08	3.3	2%
BVR-09	18.7	50%
BVR-10	2.0	5%
BVR-11	0.1	1%
Total	123.4	3.5%

[a] Sub-watersheds 1-4 consitute the lower Beaver Creek watershed; sub-watersheds 5-11 consitute the Waggys Creek watershed

[b] Percent of area contiguous to stream compared to the total pasture area in each sub-watershed.

Table 4.7. Distribution of the dairy cattle[a] population.

Month	Confined	Pasture	Streams[b]
January	638.30	367.42	0.28
February	638.30	367.42	0.28
March	269.60	735.59	0.81
April	202.20	802.65	1.15
May	202.20	802.07	1.73
June	202.20	799.77	4.03
July	202.20	799.77	4.03
August	202.20	799.77	4.03
September	202.20	802.07	1.73
October	202.20	802.65	1.15
November	269.60	735.59	0.81
December	638.30	367.42	0.28

[a] Includes milk cows, dry cows, and heifers.
[b] Number of dairy cattle defecating in stream.

Table 4.8. Distribution of the beef cattle population.

Months	Confined	Pasture	Stream[a]
January	324.01	485.72	0.30
February	365.71	548.23	0.33
March	0.00	953.51	0.87
April	0.00	969.24	1.18
May	0.00	984.65	1.81
June	0.00	998.22	4.28
July	0.00	1014.19	4.35
August	0.00	1030.16	4.42
September	0.00	1048.70	1.92
October	0.00	664.85	0.81
November	0.00	713.13	0.65
December	304.76	456.86	0.28

[a] Number of beef cattle defecating in stream.

4.2.2. Direct Manure Deposition in Streams

Direct manure loading to streams is due to both dairy (Table 4.7) and beef cattle (Table 4.8) defecating in the stream. Manure loading increases during the warmer months when cattle spend more time in water compared to the cooler months. The potential average annual manure loading directly deposited by cattle in the stream for the entire watershed is 88,723 lb. This number will vary year to year according to the amount of time that the streams in the watershed are flowing. The associated average daily fecal coliform loading to the stream is 9.0×10^{10} cfu/day; this number will also vary year to year according to the amount of time the streams in the watershed are flowing. Part of the fecal coliform deposited in the stream stays suspended while the remainder adsorbs to the sediment in the streambed. Under base flow conditions, it is likely that suspended fecal coliform bacteria are the primary form transported with the flow. Sediment-bound fecal coliform bacteria are likely to be re-suspended and transported to the watershed outlet under high flow conditions. Die-off of fecal coliform in the stream depends on sunlight, predation, turbidity, and other environmental factors.

4.2.3. Direct Manure Deposition on Pastures

Dairy (Table 4.7) and beef (Table 4.8) cattle that graze on pastures but do not deposit in streams contribute the majority of fecal coliform loading on pastures. Manure loading on pasture was estimated by multiplying the total number of each type of cattle (milk cow, dry cow, heifer, and beef) on pasture by the amount of manure produced per day. The total amount of manure produced by all types of cattle was divided by the pasture acreage to obtain manure loading (lb/ac-day) on pasture. Fecal coliform loading (cfu/ac-day) on pasture was calculated by multiplying the manure loading (lb/ac-day) by the fecal coliform content (cfu/lb) of the manure. Because the confinement schedule of the cattle changes with season, manure and fecal coliform loading on pasture also change with season.

Pasture has average annual cattle manure loadings of 32,156 lb/ac-year. The associated fecal coliform loadings from cattle to pasture on a daily basis, averaged over the year, are 1.21×10^{13} cfu/ac-day. Fecal coliform bacteria deposited on the pasture surface are subject to die-off due to desiccation and ultraviolet (UV) radiation. Runoff can transport part of the remaining fecal coliform to receiving waters.

4.2.4. Land Application of Liquid Dairy Manure

A typical milk cow weighs 1,400 lb and produces 17 gallons of liquid manure daily (ASAE, 1998). Based on the monthly confinement schedule (Table 4.5) and the number of milk cows (Table 4.7), annual liquid dairy manure production in the watershed is 1.8 million gallons. Based on the per capita fecal coliform production of milk cows, the fecal coliform concentration in fresh liquid dairy manure is 1.18×10^9 cfu/gal. Liquid dairy manure receives priority over other manure types (poultry litter and solid cattle manure) when applied to land. Liquid dairy manure application rates are 10,000 and 3,900 gal/ac-year to cropland and pasture land use categories, respectively, with cropland receiving priority in application. Based on availability of land and liquid dairy manure, as well as the assumptions regarding application rates and priority of application, it was estimated that liquid dairy manure was applied to 149 acres (39%) of cropland, 58 acres (2.6%) of hay, and 18 acres (1.4%) of pasture.

For modeling purposes, a ten-year rotation with four years of corn-rye and six years of rotational hay was assumed. It was assumed that 50% of the corn acreage was under no-till cultivation. Liquid manure is applied to cropland during February through May (prior to planting) and in October-November (after the crops are harvested). For spring application to cropland, liquid manure is applied on the soil surface to rotational hay and no-till corn, and is incorporated into the soil for corn in conventional tillage. In fall, liquid manure is incorporated into the soil for cropland under rye, and surface-applied to cropland under rotational hay. In all months except December and January, liquid manure can be surface-applied to pasture. It was assumed that only 10% of the subsurface-applied fecal coliform was available for removal in surface runoff. The application schedule for manure is given in Table 4.9. Dry cows and heifers were assumed to produce only solid manure.

Table 4.9. Schedule of cattle and poultry waste application in the Beaver Creek watershed.

Month	Liquid manure applied (%)[a]		Solid manure or poultry litter applied (%)[a]	
	Crops	Pasture	Crops	Pasture
January	0	0	0	0
February	7.1	5	6.7	5
March	35.7	25	33.3	25
April	28.6	20	26.7	20
May	7.1	5	6.7	5
June	0	10	0	5
July	0	0	0	5
August	0	5	0	5
September	0	15	0	10
October	7.1	5	13.3	10
November	14.3	10	13.3	10
December	0	0	0	0

[a] As percent of annual load applied to each land use type.

4.2.5. Land Application of Solid Manure

Solid manure produced by dry cows, heifers, and beef cattle during confinement is collected for land application. It was assumed that milk cows produce only liquid manure while in confinement. The number of cattle, their typical weights, amounts of solid manure produced, and fecal coliform concentration in fresh manure are given in Table 4.10. Solid Manure is last on the priority list for application to land (it falls behind liquid manure and poultry litter). The amount of solid manure produced in each sub-watershed was estimated based on the populations of dry cows, heifers, and beef cattle in the sub-watershed (Table 4.1) and their confinement schedules (Table 4.5). Solid manure from dry cows, heifers, and beef cattle contained different fecal coliform concentrations (cfu/lb) (Table 4.10).

Table 4.10. Estimated population of dry cows, heifers, and beef cattle, typical weights, per capita solid manure production, and fecal coliform concentration in fresh solid manure.

Type of cattle	Population	Typical weight (lb)	Solid manure produced (lb/animal-day)	Fecal coliform concentration in fresh manure (× 10^6 cfu/lb)
Dry cow	116	1,400[a]	115.0[b]	176[c]
Heifer	216	640[d]	40.7[a]	226[c]
Beef	802	1,000	60.0[b]	333[c]

[a] Source: ASAE (1998)
[b] Source: MWPS (1993)
[c] Based on per capita fecal coliform production per day (Table 4.1) and manure production
[d] Based on weighted average weight assuming that 57% of the animals are older than 10 months (900 lb ea.), 28% are 1.5-10 months (400 lb ea.) and the remainder are less than 1.5 months (110 lb ea.) (MWPS, 1993).

Solid manure is applied at the rate of 7 tons/ac-year to both cropland and pasture, with priority given to cropland. As in the case of liquid manure, solid manure is only applied to cropland during February through May, October, and November. Solid manure can be applied to pasture during the whole year, except December and January. The incorporation properties of the application of solid manure to cropland or pasture are assumed to be identical to the incorporation properties of the application of liquid dairy manure. The application schedule for solid manure is given in Table 4.9. Based on availability of land and solid manure, as well as the assumptions regarding application rates and priority of application, it was estimated that solid cattle manure was applied to 16 acres (4.2%) of cropland and 169 acres (7.6%) of hay during the calibration period. Because poultry litter is applied preferentially before solid cattle manure, and because poultry litter application rates changed for the allocation period (see section 4.3), the land available for solid cattle manure application also changed for the allocation period. Thus, the acreage receiving solid cattle manure for the allocation period was 16 acres (4.2%) of cropland, 86 acres (3.8%) of hay, and 81 acres (6.3%) of pasture.

4.3. Poultry

The poultry population (Table 4.1) was estimated based on the permitted confined feeding operations (CAFOs) located within the watershed and discussions with local producers and nutrient management specialists. The numbers in Table 4.1 correspond to the calibration period; recent changes in poultry populations in the watershed were simulated during the allocation period, reflecting an increase of 120,000 chickens and decrease of 126,000 turkeys watershed-wide. A complete listing of poultry CAFOs can be found in Table J.1 in Appendix J. Poultry litter production was estimated from the poultry population after accounting for the time when the houses are not occupied. It was known, from talking to a nutrient management specialist and consulting with DEQ records, that a good deal of manure is transferred out of the watershed. During modeling, the net change in manure was represented, reflecting an approximate 35% net transfer of manure out of the watershed (net transfer considers poultry litter transferred into and out of the watershed).

Because poultry is raised entirely in confinement, all litter produced is collected and stored prior to land application. The estimated production rate of poultry litter in the Beaver Creek watershed for the calibration period is 1.69×10^7 lb/year; after consideration of the net transfer of manure out of the watershed, poultry litter is applied at a rate of $1.08\text{x}10^7$ lb/year in the Beaver Creek watershed; this corresponds to a fecal coliform application rate of $9.62\text{x}10^{14}$ cfu/year. The corresponding figures for the allocation period are $1.33\text{x}10^7$ lb/year generated and 8.33×10^6 lb/year and $9.24\text{x}10^{14}$ cfu/year applied. The fecal coliform bacteria produced are subject to die-off in storage and losses due to incorporation prior to being subject to transport via runoff. Poultry litter was applied at the rate of 3 tons/ac-year first to cropland, and then to hay and pastures at 2.25 tons/ac-year and 1.5 tons/ac-year, respectively, for the calibration period. At the recommendation of a local nutrient management specialist, application rates for poultry litter during the allocation period (future conditions) were reduced to reflect new P-based application rates. These new rates were 2, 1.5, and 1 tons/ac-year for cropland, hay, and pasture, respectively. Poultry litter receives priority after all liquid manure has been applied (i.e., it is applied before solid cattle manure is considered). The incorporation properties of poultry litter application to cropland and pastures are assumed to be identical to the incorporation properties of cattle manure application. The application schedule of poultry litter is given in Table 4.9. As with liquid and solid manures, poultry litter is not applied to cropland during June through September. Based on availability of land and poultry litter, as well as the assumptions regarding application rates and priority of application, it was estimated that poultry litter was applied to 216 acres (57%) of cropland; 1816 acres (81%) of hay; and 460 acres (36%) of pasture during the calibration period. Initial estimates of poultry litter application for the allocation period are 216 acres (57%) of cropland; 2,090 acres (93%) of hay; and 598 acres (46%) of pasture.

4.4. Sheep

The sheep population (Table 4.1) was estimated based on discussions with local stakeholders. All sheep were located in sub-watershed 9. The sheep herd was composed of lambs and ewes. The lamb population was expressed in equivalent sheep numbers, and reflected two lambs per ewe. The equivalent sheep population calculated for lambs was based on the assumption that the average weight of a lamb is half of the weight of a sheep. The total number of sheep for the Beaver Creek watershed was the sum of the number of ewes (46) and the equivalent number of lambs (46) for a total of 92 animals. The sheep were kept on pasture at all times. Sheep are not usually confined and tend not to wade or defecate in the streams. Therefore, the fecal coliform produced by sheep was deposited directly on pasture.

Pasture in sub-watershed 9 has average annual sheep manure loadings of 2,154 lb/ac-year. Fecal coliform loadings to sub-watershed 9 from sheep on a daily basis averaged over the year are 3.94×10^{12} cfu/ac-day.

4.5. Horses

Horse total populations for the Beaver Creek watershed were obtained based on population densities in the USDA National Agricultural Statistics Service (NASS) for Rockingham County, Virginia. The total horse population was estimated to be 47 and was deemed satisfactory by local stakeholders during the Steering Committee meetings. The distribution of horse population among the sub-watersheds agreed upon by the Local Steering Committee is listed in Table 4.11. The fecal coliform produced by horses is contributed to hay (via application) and pasture areas. Fecal coliform loadings from horses on a daily basis averaged over the year and over pasture areas in the entire watershed are 2.0×10^{9} cfu/ac-day for hay and pasture areas.

Table 4.11. Horse Populations in Beaver Creek Sub-Watersheds.

Sub-watershed[a]	Horse Population
BVR-01	0
BVR-02	24
BVR-03	5
BVR-04	0
BVR-05	3
BVR-06	0
BVR-07	0
BVR-08	6
BVR-09	5
BVR-10	4
BVR-11	0
Total	47

[a] Sub-watersheds 1-4 consitute the lower Beaver Creek watershed; sub-watersheds 5-11 consitute the Waggys Creek watershed

4.6. Wildlife

Wildlife fecal coliform contributions can come from excretion of waste on land and from excretion directly into streams. Information provided by VADGIF, professional trappers, and watershed residents were used to estimate wildlife populations. Wildlife species that were found in quantifiable numbers in the watershed included deer, raccoon, muskrat, beaver, wild turkey, goose, and wood duck. Population numbers for each species and fecal coliform amounts were determined (Table 4.1) along with preferred habitat and habitat area (Table 4.12).

Professional judgment was used in estimating the percent of each wildlife species depositing directly into streams, considering the habitat area each occupied (Table 4.12). Fecal loading from wildlife was estimated for each sub-watershed. The wildlife populations were distributed among the sub-watersheds based on the area of appropriate habitat in each sub-watershed. For example, the deer population was evenly distributed across the watershed, whereas muskrat and raccoons had variable population densities based on land use and proximity to a water source. Therefore, a sub-watershed with more stream length and impoundments and more area in crop land use would have more muskrats than a sub-watershed with shorter stream length and fewer impoundments, and less area in crop land use. Distribution of wildlife among sub-watersheds is given in Table 4.13.

Table 4.12. Wildlife habitat and densities description and percent direct fecal deposition in streams.

Wildlife type	Habitat	Population Density (animal / mi² -habitat)	Direct fecal deposition in streams (%)
Deer	Entire Watershed	30	1%
Raccoon	low density on forests not in high density area; high density on forest within 600 ft of a permanent water source or 0.5 mile of cropland	Low density: 10 High density: 30	10%
Muskrat	16/mile of ditch or medium sized stream intersecting cropland; 8/mile of ditch or medium sized stream intersecting pasture; 10/mile of pond or lake edge; 50/mile of slow-moving river edge	-see habitat column-	25%
Beaver	300 ft buffer streams and impoundments in forest and pasture	9.6	50%
Geese	300 ft buffer around main streams	50 – off season 70 – peak season	25%
Wood Duck	300 ft buffer around main streams	40 – off season 60 – peak season	25%
Wild Turkey	Entire Watershed except urban and farmstead	6.4	1%

Table 4.13. Distribution of wildlife among sub-watersheds.

Sub-watershed[a]	Deer	Raccoon	Muskrat	Beaver	Geese		Wood Duck		Wild Turkey
BVR-01	2	1	0	0	2	2	1	2	1
BVR-02	80	15	17	2	12	17	10	15	17
BVR-03	52	11	0	3	0	0	0	0	11
BVR-04	29	7	6	1	4	6	3	5	6
BVR-05	22	4	6	1	4	5	3	4	6
BVR-06	8	1	1	0	0	1	0	1	0
BVR-07	3	0	3	0	2	2	1	2	1
BVR-08	34	10	0	2	0	1	0	0	7
BVR-09	49	33	4	2	10	13	8	11	10
BVR-10	44	23	0	3	0	0	0	0	9
BVR-11	157	78	0	4	12	16	9	12	34
Total	480	183	37	18	46	63	35	54	102

[a] Sub-watersheds 1-4 consitute the lower Beaver Creek watershed; sub-watersheds 5-11 consitute the Waggys Creek watershed

4.7. Summary: Contribution from All Sources

Based on the inventory of sources discussed in this chapter, a summary of the contribution by the different nonpoint sources to direct annual fecal coliform loading to the streams is given in Table 4.14. Distribution of annual fecal coliform loading from nonpoint sources among the different land use categories is also given in Table 4.14.

From Table 4.14, it is clear that nonpoint source loadings to the land surface are nearly 320 times larger than direct nonpoint loadings to the streams, with pastures receiving about 94% of the total fecal coliform load. It could be prematurely assumed that most of the fecal coliform loading in streams originates from upland sources, primarily from pastures. However, other factors; such as precipitation amount and pattern, manure application activities (time and method), type of waste (solid versus liquid manure), and proximity to streams also impact the amount of fecal coliform from upland areas that reaches the streams. The HSPF model considers these factors when estimating fecal coliform loads to the receiving waters, as described in Chapter 5.

Table 4.14. Annual fecal coliform loadings to the stream and the various land use categories in the Beaver Creek watershed.

Source	Fecal coliform loading ($x10^{12}$ cfu/year)		Percent of total loading	
	Calibration Period	Allocation Period	Calibration Period	Allocation Period
Direct loading to streams				
Cattle in stream	33.0	33.0	0.2%	0.2%
Wildlife in stream	14.8	14.8	<0.1%	<0.1%
Straight pipes	4.9	4.9	<0.1%	<0.1%
Loading to land surfaces				
Cropland	183	155	0.1%	0.1%
Hay	824	795	4.8%	4.7%
Pasture	15,731	15,749	93.2%	93.5%
Residential[a]	20.2	20.2	0.1%	0.1%
Forest	65	65	0.4%	0.4%
Total	16,876	16,837		

[a] Includes loads received from both High and Low Density Residential due to failed septic systems and pets.

CHAPTER 5: MODELING PROCESS FOR BACTERIA TMDL DEVELOPMENT

A key component in developing a TMDL is establishing the relationship between pollutant loadings (both point and nonpoint) and in-stream water quality conditions. Once this relationship is developed, management options for reducing pollutant loadings to streams can be assessed. In developing a TMDL, it is critical to understand the processes that affect the fate and transport of the pollutants and cause the impairment of the waterbody of concern. Pollutant transport to water bodies is evaluated using a variety of tools, including monitoring, geographic information systems (GIS), and computer simulation models. In this chapter, the modeling process, input data requirements, and model calibration procedure and results are discussed.

5.1. Model Description

The TMDL development requires the use of a watershed-based model that integrates both point and nonpoint sources and simulates in-stream water quality processes. The Hydrologic Simulation Program – FORTRAN (HSPF) version 12 (Bicknell *et al.*, 2001; Duda *et al.*, 2001) was used to model fecal coliform transport and fate in the Beaver Creek watershed. The ArcGIS 9.1 GIS program was used to display and analyze landscape information for the development of input for HSPF.

The HSPF model simulates nonpoint source runoff and pollutant loadings, performs flow routing through streams, and simulates in-stream water quality processes. HSPF estimates runoff from both pervious and impervious parts of the watershed and stream flow in the channel network. The sub-module PWATER within the module PERLND simulates runoff, and hence, estimates the water budget on pervious areas (e.g., agricultural land). Runoff from largely impervious areas is modeled using the IWATER sub-module within the IMPLND module. The simulation of flow through the stream network is performed using the sub-modules HYDR and ADCALC within the module RCHRES. While HYDR routes the water through the stream network, ADCALC calculates variables used for simulating convective transport of the pollutant in the stream. Fate of fecal coliform on pervious and impervious land segments is simulated using the PQUAL (PERLND module) and IQUAL (IMPLND module) sub-modules, respectively. Fate of fecal coliform in stream water is simulated using the general constituent pollutant (GQUAL) sub-module within RCHRES module. Fecal coliform bacteria are simulated as dissolved pollutants in the GQUAL sub-module.

5.2. Input Data Requirements

The HSPF model requires a wide variety of input data to describe hydrology, water quality, and land use characteristics of the watershed. The different types and sources of input data used to develop the TMDLs for the Beaver Creek watershed are discussed below.

5.2.1. Climatological Data

Weather data needed to conduct simulations were obtained from the weather station closest to the watershed. Hourly precipitation data were obtained from Dale Enterprise weather station in Rockingham County. Because hourly data for other meteorological parameters were not available at dale Enterprise, daily data from Lynchburg Airport (Virginia) and Elkins Airport (West Virginia) were used to complete the meteorological data set required for running HSPF. Detailed descriptions of the weather data and the procedure for converting the raw data into the required data set are presented in Appendix D.

5.2.2. Model Parameters

The hydrology parameters required by HSPF were defined for every land use category for each sub-watershed. Hydrology parameters required for the PWATER, IWATER, and HYDR ADCALC sub-modules are listed in the HSPF Version 12 User's Manual (Bicknell *et al.*, 2001). Water quality parameters required as inputs for PQUAL, IQUAL, and GQUAL are also given in the HSPF User's Manual (Bicknell *et al.*, 2001). Runoff estimated by the model is an input to the water quality components. Values for the parameters were either estimated based on local conditions when applicable (e.g., for land slopes) or taken from calibrated Muddy Creek values. In addition to the land use-specific parameters, each reach requires a function table (FTABLE) to describe the relationship between water depth, surface area, volume, and discharge (Bicknell *et al.*, 2001). The FTABLE parameters were estimated using a digital elevation model (DEM) of the area in addition to relationships developed by the NRCS that relate stream characteristics to drainage area. Information on the calculated stream geometry for each sub-watershed is presented in Table 5.1 for the bankfull condition.

Table 5.1. Stream Characteristics of Beaver Creek.

Sub-watershed[a]	Stream length (mile)	Average bankfull width (ft)	Average bankfull channel depth (ft)	Slope (ft/ft)
BVR-01	0.42	38	3.6	0.0161
BVR-02	2.23	37	3.5	0.0024
BVR-03	3.56	17	1.8	0.0103
BVR-04	1.73	13	1.5	0.0130
BVR-05	0.64	33	3.2	0.0092
BVR-06	0.11	31	3.0	0.0077
BVR-07	0.31	31	3.0	0.0063
BVR-08	2.37	14	1.6	0.0339
BVR-09	2.59	28	2.8	0.0163
BVR-10	1.77	16	1.7	0.0909
BVR-11	4.02	26	2.6	0.0702

[a] Sub-watersheds 1-4 consitute the lower Beaver Creek watershed; sub-watersheds 5-11 consitute the Waggys Creek watershed

5.2.3. Accounting for Spring Flows In Beaver Creek

As previously mentioned, Beaver Creek has a significant spring that contributes to its flow even during times of drought. An average spring flow rate of 24.6 cfs was calculated from three observations taken by DEQ prior to the start of the modeling process. Based on consultations with local residents of the watershed, the flow rate was considered to be constant through out the year.

5.3. Accounting for Pollutant Sources

5.3.1. Overview

There were 7 VADEQ permitted bacteria point sources in the Beaver Creek watershed. All seven of the permitted sources were general permits for facilities/residences discharging at or less than 1000 gallons per day (Table 4.2).

Bacteria loads that are directly deposited by cattle and wildlife in streams were treated as direct nonpoint sources in the model. Bacteria that were land-applied or deposited on land were treated as nonpoint source loadings; all or part of that load may be transported to the stream as a result of surface runoff during rainfall events. Direct nonpoint source loading was applied to the stream reach in each sub-watershed as appropriate. The point sources permitted to discharge bacteria in the watershed were incorporated into the simulations at the stream locations designated in the permit.

The nonpoint source loading was applied in the form of fecal coliform counts to each land use category in a sub-watershed. Fecal coliform die-off was simulated while manure was being stored, while it was on the land, and while it was transported in streams. Both direct nonpoint and nonpoint source loadings were varied by month to account for seasonal differences such as cattle and wildlife access to streams.

We developed a spreadsheet program internally (Zeckoski et al., 2005) and used it to generate the nonpoint source fecal coliform inputs to the HSPF model. This spreadsheet program takes inputs of animal numbers, land use, and management practices by sub-watershed and outputs hourly direct deposition to streams and monthly loads to each land use type. We customized the program to allow direct deposition in the stream by dairy cows, ducks, and geese to occur only during daylight hours. The spreadsheet program calculates the manure produced in confinement by each animal type (dairy cows, beef cattle, and poultry) and distributes this manure to available lands (crops, hay, and pasture) within each sub-watershed. If a sub-watershed does not have sufficient land to apply all the manure its animals generate, the excess manure is distributed equally to other sub-watersheds that have land that has not yet received manure.

5.3.2. Modeling fecal coliform die-off

Fecal coliform die-off was modeled using first order die-off of the form:

$$C_t = C_0 10^{-Kt} \qquad [5.1]$$

where: C_t = concentration or load at time t,

C_0 = starting concentration or load,

K = decay rate (day^{-1}),

and t = time in days.

A review of literature provided estimates of decay rates that could be applied to waste storage and handling in Beaver Creek watershed (Table 5.2).

Table 5.2. First order decay rates for different animal waste storage as affected by storage/application conditions and their sources.

Waste type	Storage/application	Decay rate (day^{-1})	Reference
Dairy manure	Pile (not covered)	0.066	Crane and Moore (1986)
	Pile (covered)	0.028	
Beef manure	Anaerobic lagoon	0.375	Crane and Moore (1986)
Poultry litter	Soil surface	0.035	Giddens *et al.* (1973)
		0.342	Crane *et al.* (1980)

Based on the values cited in the literature, the following decay rates were used in simulating fecal coliform die-off in stored waste.

- Liquid dairy manure: Because the decay rate for liquid dairy manure storage could not be found in the literature, the decay rate for beef manure in anaerobic lagoons (0.375 day^{-1}) was used.
- Solid cattle manure: Based on the range of decay rates (0.028-0.066 day^{-1}) reported for solid dairy manure, a decay rate of 0.05 day^{-1} was used, assuming that a majority of manure piles are not covered.

- Poultry waste in pile/house: Because no decay rates were found for poultry waste in storage, a decay rate of 0.035 day^{-1} was used based on the lower decay rate reported for poultry litter applied to the soil surface. The lower value was used instead of the higher value of 0.342 day^{-1} (Table 5.2) because fecal coliform die-off in storage was assumed to be lower, given the absence of UV radiation and predation by soil microbes.

The procedure for calculating fecal coliform counts in waste at the time of land application is included in Appendix C. Depending on the duration of storage, type of storage, type of manure, and die-off factor, the fraction of fecal coliform surviving in the manure at the end of storage is calculated. While calculating survival fraction at the end of the storage period, the daily addition of manure and coliform die-off of each fresh manure addition is considered to arrive at an effective survival fraction over the entire storage period. The amount of fecal coliform available for application to land per year is estimated by multiplying the survival fraction with total fecal coliform produced per year (in as-excreted manure). Monthly fecal coliform application to land is estimated by multiplying the amount of fecal coliform available for application to land per year by the fraction of manure applied to land during that month. A base-10 decay rate of 0.05 day^{-1} was assumed for fecal coliform on the land surface. The decay rate of 0.05 day^{-1} is represented in HSPF by specifying a maximum surface buildup of nine times the daily loading rate. An in-stream decay rate of 1.15 day^{-1} was used.

5.3.3. Modeling Nonpoint Sources

For modeling purposes, nonpoint fecal coliform loads were those that were deposited or applied to land and, hence, required surface runoff events for transport to streams. Fecal coliform loading by land use for all sources in each sub-watershed is presented in Chapter 4:. The existing condition fecal coliform loads are based on best estimates of existing wildlife, livestock, and human populations and fecal coliform production rates. Fecal coliform in stored waste was adjusted for die-off prior to the time of land application when calculating loadings to cropland and pasture. For a given period of storage, the total amount of fecal coliform present in the stored manure was adjusted for die-off on a daily basis. Fecal coliform loadings to each sub-watershed in the Beaver Creek watershed are presented in Appendix F. The sources of fecal coliform to different land use categories and how the model handled them are briefly discussed below.

1. Cropland: Liquid dairy manure and solid manure are applied to cropland as described in Chapter 4:. Fecal coliform loadings to cropland were adjusted to account for die-off during storage and partial incorporation during land application. Wildlife contributions were also added to the cropland areas. For modeling, the monthly fecal coliform loading assigned to cropland was distributed over the entire cropland acreage within a sub-watershed. Thus, loading rate varied by month and sub-watershed.
2. Pasture: In addition to direct deposition from livestock and wildlife, pastures receive applications of liquid dairy manure and solid manure as described in Chapter 4:. Applied fecal coliform loading to pasture was reduced to account for die-off during storage. For modeling, the monthly fecal coliform loading assigned to pasture was distributed over the entire pasture acreage within a sub-watershed.
3. Hay: Hay received applications of liquid dairy manure and solid manure as described in Chapter 4. Applied fecal coliform loading to hay was reduced to account for die-off during storage. For modeling, the monthly fecal coliform loading assigned to hay was distributed over the entire hay acreage within a sub-watershed. Hayland also received direct deposits from wildife.
4. Low Density Residential: Fecal coliform loading on rural residential land use came from failing septic systems and waste from pets. In the model simulations, fecal coliform loads produced by failing septic systems and pets in a sub-watershed were combined and assumed to be uniformly applied to the low density residential pervious land use areas. Impervious areas (Table 3.1) received constant loads of 1.0×10^7 cfu/acre/day.

5. High-Density Residential: Fecal coliform loading to the high density residential land use came from pets in these areas; the impervious load was assumed to be a constant 1.0×10^7 cfu/acre/day (USEPA, 2000).
6. Forest: Wildlife not defecating in streams, cropland, or pastures provided fecal coliform loading to the forested land use. Fecal coliform from wildlife in forests was applied uniformly over the forest areas in each sub-watershed.

5.3.4. Modeling Direct Nonpoint Sources

Fecal coliform loads from direct nonpoint sources included cattle in streams, wildlife in streams, and direct loading to streams from straight pipes from residences. Loads from direct nonpoint sources in each sub-watershed are described in detail in Chapter 4. Contributions of fecal coliform from interflow and groundwater were modeled as having a constant concentration of 30 cfu/100mL for interflow and 20 cfu/100mL for groundwater.

5.4. Model Calibration and Validation

Model calibration is the process of selecting model parameters that provide an accurate representation of the watershed. In this section, the procedures followed for calibrating the hydrology and water quality components of the Hydrological Simulation Program-FORTRAN (HSPF) model are discussed.

5.4.1. Hydrology

No hydrology calibration was conducted on Beaver Creek watershed due to the lack of observed flow data. However, hydrological parameters in HSPF had to be set to “reasonable” values because the output of the hydrological component of HSPF impacts fecal coliform predictions. Some of those parameters were estimated based on watershed characteristics, while others were based on the characteristics of the nearby Muddy Creek watershed. Table 4.13 at the end of this section lists the different hydrologic parameters and specifies the source of each parameter.

To assist in the characterization of the Beaver Creek watershed for the HSPF model, the Department of Environmental Quality (DEQ) collected flow samples at four points in the watershed in December 2004, January 2005, and February 2005 (Figure 5.1, Table 5.3). These data were used in multiple ways. The flow rates of the spring (point 3) taken before modeling began (the first three points) were used to generate a constant spring flow rate used in the model: 24.6 cfs. Based upon flow records from the nearby Muddy Creek watershed it was determined that the observed flows for Beaver Creek in December 2004 were likely a bit higher than normal, while the flows from January and February of 2005 were likely slightly lower than normal.

Table 5.3. Flow data collected by DEQ staff.

	Site No.			
	1	2	3	4
Site Description:	Union Springs Run Below Dam	Waggys Creek before confluence with Beaver Creek	Beaver Creek Spring at Source	Beaver Creek before confluence with Waggys Creek
Date	Flow Rate (cfs)			
12/6/2004		14.8	28.1	29.5
12/17/2004		12	24.2	28.2
1/12/2005	2.59	4.29	21.5	22.2
1/31/2005	2.88	4.99	21.7	22
2/8/2005	2.06	3.44	18.4	20.5
Average Observed Flow	2.51	7.90	22.8	24.5
Modeled Flow	2.2[a]	4.9[a]	24.6[b]	25.1[a]

[a]Flow simulated by the model
[b]Flow rate input to the model

Additionally, the simulated flow rate for the calibration period (January 1999-June 2003) for Waggys Creek above its confluence with Beaver Creek (outlet of sub-watershed 5), for Beaver Creek above its confluence with Waggys Creek (outlet of sub-watershed 4), and for the flow output of Union Springs Dam (outlet of sub-watershed 11) were compared to the observed flow rates at those points (the 'Modeled Flow' row in Table 5.3). As can be seen in the table, the simulated flow rates seem reasonable. The simulated period did not (and could not due to data limitations) cover the period of observed data, so an exact match is not expected. Detailed specifications for the Union Springs Dam were obtained from the Natural Resource Conservation Service (NRCS) in Richmond and used in the model.

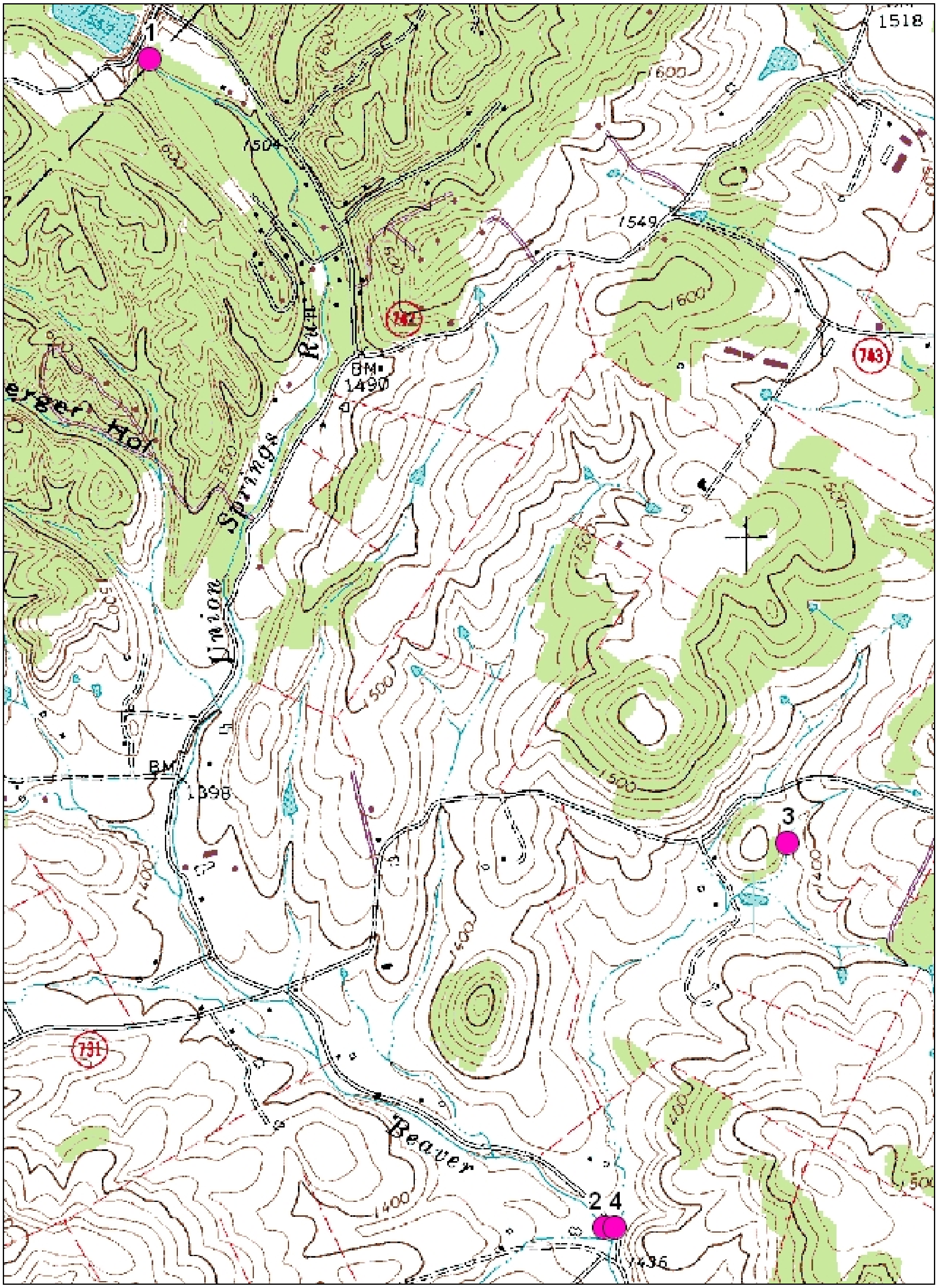

Figure 5.1. Location of flow monitoring stations.

5.4.2. Water Quality calibration

5.6.2.a. Direct Deposition of Feces at Very Low Flows

We modeled direct deposition of feces in streams by livestock and wildlife considering both flow depth and flow stagnation. Fecal coliform inputs by livestock and wildlife in streams are typically simulated without regard to stream depth. Under extreme low flow conditions, one cow or deer defecating once in a stream reach can result in a violation of the instantaneous water quality standard; however, under such extreme low flows, it is not likely for animals to wade in or drink from the stream. Therefore, modeled direct deposition of feces at extreme low flow conditions can cause unrealistically high numbers of violations, make calibration difficult, and adversely affect the quality of the final calibration. Additionally, the HSPF model is capable of simulating extremely low flows for a volume of water that would in reality be filling depressions in the reach – stagnant, non-flowing water.

In order to more accurately model the water quality conditions in Beaver Creek, we used a calibrated stage (stream depth) of 0.67 inches as a cutoff for cattle direct deposition of manure and 0.54 inches as a cutoff for wildlife deposition of scat. When the stream depth fell below either of those two thresholds, direct deposition by the corresponding animal category was set to zero; at stream depth values greater than threshold values, direct deposition was left unchanged. This type of cutoff can be thought of as a behavioral cutoff as it is designed to reflect changes in animal behavior at very low flow conditions.

A flow stagnation volume was incorporated into the model to account for situations where water would be ponding in the streams with no detectable flow. When the total volume of water in a reach dropped to (0.5 in * surface area of the reach), the discharge rate of the reach was set to zero. This volume is non-behavioral as it reflects a physical change in the flow of water, not a change in patterns of bacteria deposition. Under these extremely low flow conditions, bacteria loadings to streams from straight pipes, permitted discharge sources, and groundwater and interflow continue while the flow stagnates. These loads are subject to die-off in the stream until sufficient flow exists to transport them downstream.

The flow-stagnation volume is modeled in HSPF by adjusting the FTABLES. In HSPF, the FTABLES define the relationship between the volume of water in a reach and the flow rate in a reach. Situations where water is ponding in a reach with no detected flow may be represented by having an entry in the FTABLE that has a water volume but zero discharge. The water volume in the reach would then have to build up past this stagnation volume before flow would begin again. During flow stagnation, bacteria are not transported downstream and are subjected to die-off until sufficient water fills the reach to allow flow to begin again.

In order to test the validity of these assumptions, HSPF was run with the original direct deposit inputs and also with the different cutoff scenarios using calibrated values for water quality parameters. Summary statistics of this comparison between simulated values and data observed at the VADEQ monitoring station are given in Table 5.4. It is evident that each additional cutoff reduces the fecal coliform concentrations. One of the important advantages of the stagnation cutoff is its influence on the maximum concentration predicted by the model. In the case of Beaver Creek, the maximum fecal coliform concentration was reduced to 321,000 cfu/100mL from an unrealistic pre-cutoff value of 106,000,000 cfu/100mL. This reduction has an important impact on the proposed reduction in bacteria sources required for the allocation scenarios; forcing an unrealistic 106,000,000 cfu/100 mL to come into standards compliance would require unnecessarily harsh reductions in bacteria loads in the watershed.

Table 5.4. Simulated and Observed Water Quality Characteristics.

	Geometric Mean	Average	Instantaneous Violations	Maximum	Minimum
Observed (VADEQ)	480	1,620	48%	8,000*	100*
Simulated with Flow Stagnation, cattle depth cutoff, and wildlife depth cutoff	468	917	48%	321,000	34
Simulated with Flow Stagnation and cattle depth cutoff	591	1,082	65%	321,000	21
Simulated with Flow Stagnation	1,412	3,727	87%	321,000	23
Simulated without any cutoff	1,477	6,860	87%	106,000,000	10**

* These are capped values
** The minimum was artificially set to 10, as the near-zero flows caused an error in bacteria concentration predictions (for further explanation, see Benham et al., 2004)

To be completely accurate, the fecal coliform direct deposit loading removed as a result of the depth cutoff should be reapplied to the appropriate land use areas. Fecal coliform not deposited in streams by cattle should be applied to pasture areas while the fecal coliform not deposited to streams by wildlife should be applied to pasture, cropland, and forest areas according to each animal's habitat preference. In this light, cutoff direct deposit fecal coliform loads that were greater than 1% of bacterial loadings to relevant land surfaces were considered significant losses that would need to be reapplied to the land surface. Cutoff loads less than 1% of land surface loads were considered insignificant.

Table 5.5 and Table 5.6 compare the average annual direct deposit fecal coliform loading input to each reach with and without cutoffs for cattle and wildlife, respectively. The calibrated cutoff values used in these tables are 0.54 inches for wildlife and 0.67 inches for cattle. The difference in these values was assumed to be the amount of fecal coliform 'lost' by imposing the cutoffs. For sub-watersheds with a difference in direct deposit loadings, the amount of fecal coliform loading to the land (resulting from manure application, cattle deposits, and wildlife deposits) was calculated. For Beaver Creek, none of the sub-watersheds had a value of 'lost' cattle direct deposit fecal coliform that was greater than 1% of the total fecal coliform received by pasture. Additionally, none of the sub-watersheds had a value of 'lost' wildlife direct deposit fecal coliform that was greater than 1% of the total fecal coliform received by pasture, cropland, and forest. Even without consideration of this 1% criterion, the 'lost' fecal coliform numbers were so small compared to the land loadings used in the model that, were they to be added to the land loadings, the actual numbers used to represent the land loadings in the HSPF input file would not change due to its formatting-imposed limitations on significant figures. Therefore, no 'lost' bacteria were reapplied to the land surface.

Table 5.5. Details on 'Lost' Fecal Coliform for Cattle during the Calibration Period.

Reach	Direct Cattle Deposit loading w/o cutoff (cfu/yr)	Direct Cattle Deposit loading w/ depth cutoff (annual ave) (cfu/yr)	Difference in Cattle Direct Deposit loadings ('Lost' FC) (cfu/yr)	Pasture-Applied Fecal Coliform by Sub-watershed (cfu/yr)	Percent 'Lost' FC is of Pasture-Applied FC (%)
1	1.80E+11	1.80E+11	0.00E+00	7.45E+13	0.00
2	7.36E+12	7.36E+12	0.00E+00	4.62E+15	0.00
3	0.00E+00	0.00E+00	0.00E+00	2.68E+15	0.00
4	3.20E+12	3.20E+12	0.00E+00	1.11E+15	0.00
5	4.95E+12	1.76E+12	3.19E+12	1.88E+15	0.17
6	1.09E+10	2.99E+09	7.95E+09	1.53E+13	0.05
7	1.14E+13	2.92E+12	8.45E+12	1.69E+15	0.50
8	7.93E+11	3.93E+10	7.54E+11	1.80E+15	0.04
9	4.51E+12	1.01E+12	3.50E+12	8.14E+14	0.43
10	5.83E+11	2.11E+10	5.62E+11	9.14E+15	0.01
11	2.73E+10	2.73E+10	0.00E+00	1.24E+15	0.00

Table 5.6. Details on 'Lost' Fecal Coliform for Wildlife during the Calibration Period.

Reach	Direct Wildlife Deposit loading w/o cutoff (cfu/yr)	Direct Wildlife Deposit loading w/ depth cutoff (annual ave) (cfu/yr)	Difference in Wildlife Direct Deposit loadings ('Lost' FC) (cfu/yr)	Applied Fecal Coliform to Pasture, Hay, Cropland, and Forest by Sub-watershed (cfu/yr)	Percent 'Lost' FC is of Pasture-Applied FC (%)
1	4.78E+11	4.78E+11	0.00E+00	7.99E+13	0.00
2	3.96E+12	3.96E+12	0.00E+00	5.00E+15	0.00
3	9.03E+10	6.77E+10	2.26E+10	2.95E+15	<0.01
4	1.30E+12	1.30E+12	0.00E+00	1.21E+15	0.00
5	1.15E+12	9.96E+11	1.51E+11	1.92E+15	0.01
6	1.60E+11	1.43E+11	1.65E+10	4.54E+13	0.04
7	4.85E+11	4.06E+11	7.95E+10	1.70E+15	<0.01
8	1.00E+11	5.01E+10	5.03E+10	1.92E+15	<0.01
9	3.05E+12	2.55E+12	4.98E+11	8.43E+14	0.06
10	1.01E+11	4.36E+10	5.79E+10	9.41E+15	<0.01
11	3.89E+12	3.89E+12	0.00E+00	1.63E+15	0.00

5.6.2.b. Beaver Creek Calibration Using Direct Deposition Cutoffs

The water quality calibration was performed at an hourly time step using the HSPF model. The water quality calibration period was January 1, 1999 through June 30, 2003. Fecal coliform concentration was output from the HSPF model on both an hourly and daily timestep. Hourly *E. coli* concentrations were determined using the following translator equation supplied by DEQ:

$$\log_2 EC(cfu/100mL) = -0.0172 + 0.91905 * \log_2 FC(cfu/100mL) \quad [5.1]$$

The *E. coli* translator was implemented in the HSPF simulation using the GENER block. The geometric mean was calculated on a monthly basis as the calendar-month geometric mean of daily average values.

Typically during a TMDL, twelve months of Bacteria Source Tracking (BST) data are collected. However, in part due to a short amount of time, and in part due to the varied nature of the land use and animal populations throughout the watershed, the BST for Beaver Creek was collected once a month for four months at three locations (Figure 5.2). The specific collection dates were October 10 and November 22, 2004; and December 14 and January 11, 2005. The BST monitoring points roughly correspond to the outlets of sub-watersheds 2, 7, and 9, respectively. Station 1BUSR001.24 is located within sub-watershed 9, but the contributing area to this station is completely forested (Figure 5.2). Because the outlet of sub-watershed 9 also includes agricultural and residential areas, the wildlife signature simulated at the outlet of sub-watershed 9 can be expected to be slightly lower than that observed at station 1BUSR001.24. The BST results for Beaver Creek are shown in Table 5.7. The weighted average presented in this table weights the contributions from each source based on the number of isolates obtained from each BST sample, the concentration of E. coli in each BST sample, and the flow rate at the time of the sample. Because flow rate for Beaver Creek was not available at the times that BST samples were collected, the flow rate of nearby Muddy Creek was used to weight the samples.

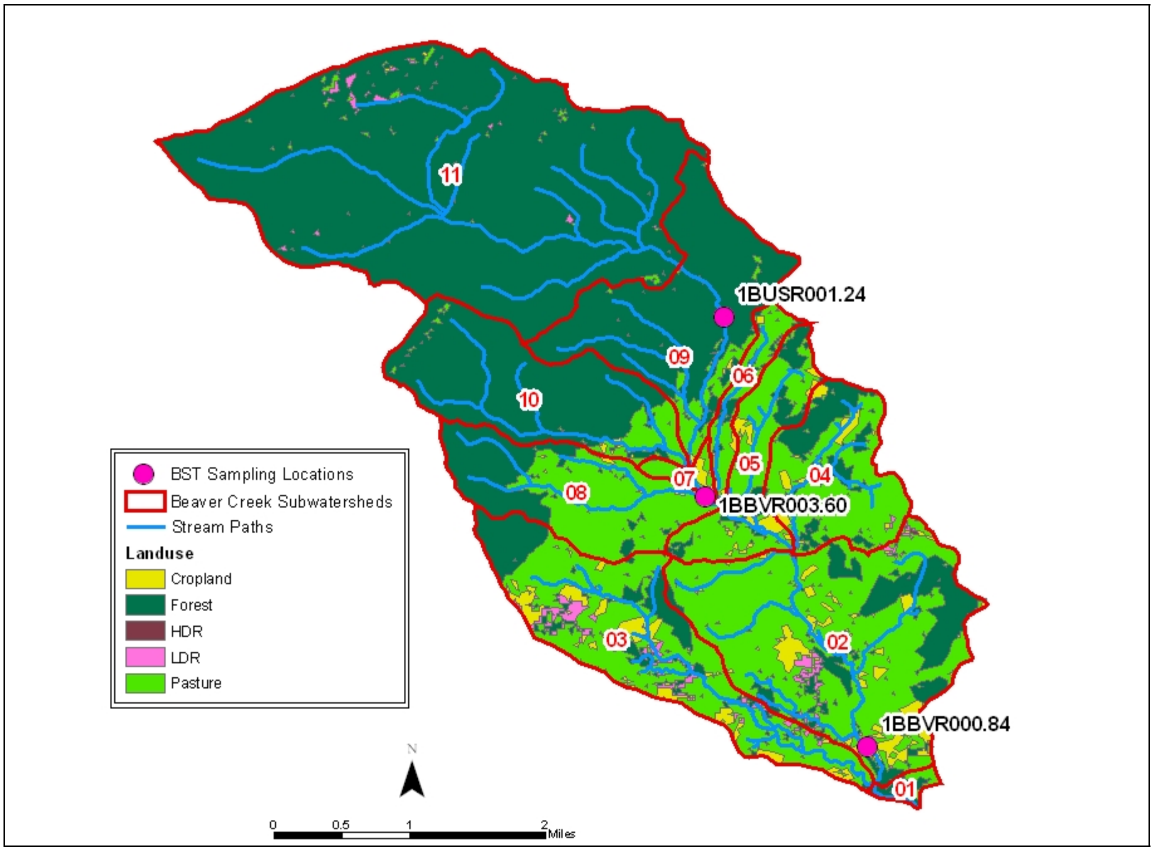

Figure 5.2. BST Stations in the Beaver Creek watershed.

Table 5.7. Bacterial source tracking results at the Beaver Creek Stations.

Station ID	*E. coli* Conc. (cfu/100 mL)	Livestock (%)	Wildlife (%)	Human (%)	Pet (%)
1BUSR001.24[1]	**15** (4; 150)[2]	**30** (0; 50)	**30** (0; 30)	**30** (0; 30)	**11** (10; 100)
1BBVR003.60	**83** (14; 560)	**40** (4; 50)	**45** (29; 84)	**6** (4; 22)	**9** (8; 22)
1BBVR000.84	**204** (86; 710)	**36** (0; 43)	**27** (4; 33)	**11** (0; 21)	**26** (12; 96)

[1]only three viable samples were collected for this station; the last sample contained insufficient bacteria for analysis
[2]numbers in parentheses indicate the range of BST results for the four samples in cfu/100 mL for the concentration and % for the signatures

The BST science is still under development. Therefore, the results presented in Table 5.7 should be considered an estimation of the bacteria contributions in the watershed, not absolute numbers. The samples were collected in a period that could not be simulated due to lack of weather data, and so a direct comparison to simulated data was not possible. In consideration of the following analysis of the simulated data, recall that the observed data are the results of, at best, four grab samples, whereas the simulated data are attempting to represent the overall continuous trend for a period of four and half years.

In order to generate numbers for comparison to the observed BST data, the HSPF model was executed nine times, each time isolating one source of bacteria in the simulation. This source breakdown analysis is shown in Table 5.8 for the outlets of the three sub-watersheds of interest; these breakdowns include contributions from all areas upstream of these watershed outlets. Only 8 sources are represented in Table 5.8 because the contributions from impervious surfaces were negligible. The source breakdown used a similar weighting as that used for the observed BST samples, wherein each day of simulation was treated as a BST sampling day, and the percent contributions for each day were weighted with the daily flow rate and daily bacteria concentration in order to produce the simulation-period averages presented in Table 5.8. The minimum and maximum values presented are the minimum and maximum daily percent contributions simulated for the calibration period.

Table 5.8. Source breakdown analysis of HSPF bacteria predictions for Beaver Creek (all values in percent); the bold values highlight the categories that correspond to the BST analysis.

Sub-watershed	Livestock DD	Livestock Land	Wildlife DD	Wildlife Land	Septic Systems	Straight Pipes	Pets	Interflow and Groundwater
	2.70	73.35	10.96	1.27	2.38	7.62	1.03	0.68
9	**76.05**		**12.24**		**10.00**		**1.03**	0.68
	(0; 98.40)[1]		(0.05; 82.45)		(0.02; 91.76)		(0; 2.10)	
	0.95	30.92	13.62	0.17	0.25	51.02	0.11	2.94
7	**31.87**		**13.80**		**51.27**		**0.11**	2.94
	(0; 99.41)		(0.02; 84.02)		(0; 91.28)		(0; 1.26)	
	4.35	90.79	2.76	0.57	0.38	0.80	0.15	0.20
2	**95.14**		**3.32**		**1.18**		**0.15**	0.20
	(0.01; 99.30)		(0.01; 72.89)		(0; 16.87)		(0; 0.53)	

[1]numbers in parentheses indicate the daily (minimum; maximum) source contributions for the simulation period

Inspection of Table 5.8 shows that livestock and wildlife have the strongest consistent signatures in the BST analysis. This trend is reflected in the simulated data as well. As expected, at the sampling point in sub-watershed 2, the wildlife signature declines as the contributions from livestock increase. The wildlife signature is much more prominent in the upstream heavily forested watersheds 7 and 9. One might expect a larger source contribution in sub-watershed 9 from wildlife than that simulated; in fact, if flow weighting is not considered, the majority of the daily contributions come from wildlife, but during runoff events (where water is transporting manure from nearby fields) the livestock, which produce much more bacteria per capita, dominate the contributions to the stream. Because the flow weighting gives more weight to these higher flow events, the reported percent contribution is higher than wildlife.

Because the BST samples are grab samples, one would expect that the observed contributions from each source would fall within the range of simulated contributions from each source. This is true for all contributions from livestock and wildlife. This is true for the contributions from humans for sub-watersheds 7 and 9. The maximum contribution observed for sub-watershed 2 is very close to the maximum simulated for sub-watershed 2. The pet contributions observed are much higher than those simulated. The observed pet contributions are surprising, given the usual location of pet defecation (i.e., upland of the stream, or for cats, inside in a litterbox) and the population of pets compared to the population of all other animals in the watershed. The simulated pet signatures seem to fit much better with typical pet defecation patterns than the observed signatures. During BST analysis, it can be difficult to completely differentiate human and pet signatures; this may, in part, explain the difference between the observed and simulated contributions from pets. Contributions from interflow and groundwater cannot be targeted as to the precise source, and thus, although their contributions are presented in Table 5.8, they cannot be classified into the BST categories. The contributions from these sources may actually contribute to the source signature of any of the categories. Overall, the simulated percent contributions from each source compare well with the observed BST data.

In addition to correlating well with the BST results, the simulated fecal coliform concentrations agree well with the observed fecal coliform concentrations. Figure 5.3 shows the daily average simulated fecal coliform concentrations and the observed data from the DEQ sampling station. At the DEQ sampling station the maximum observed concentration was a capped value of 8,000 cfu/100 mL. The overall maximum simulated concentration was 321,000 cfu/100 mL.

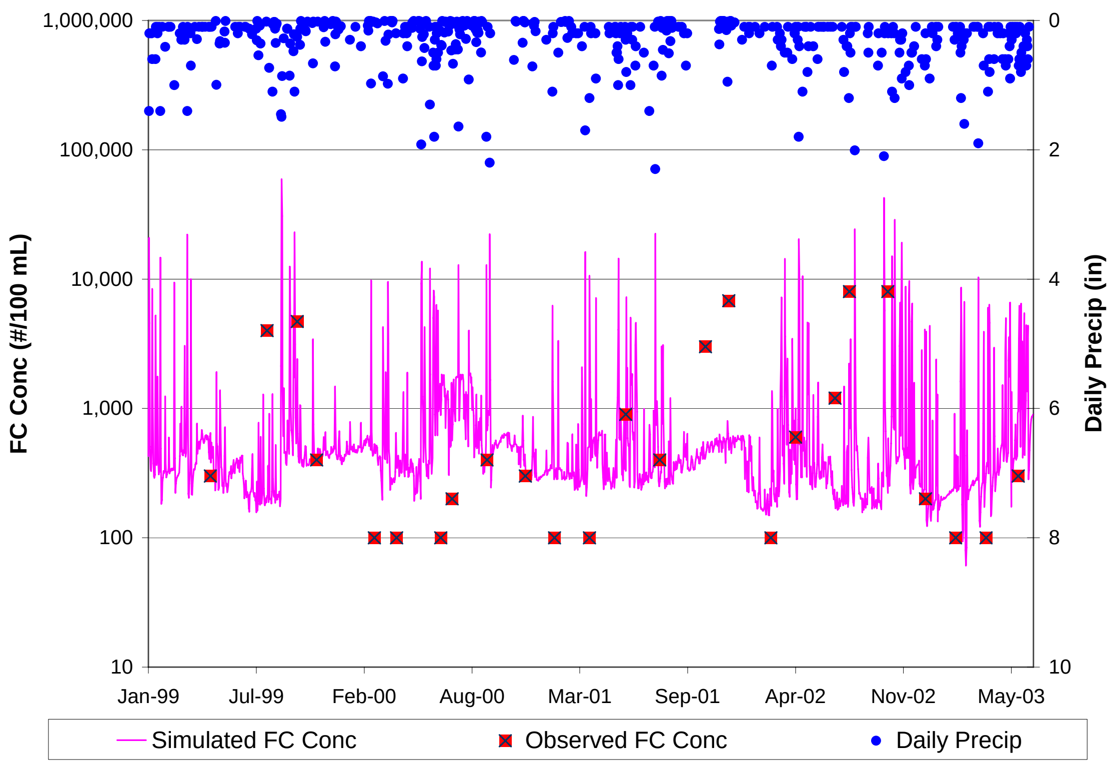

Figure 5.3. Observed Concentrations and Simulated Fecal Coliform Concentrations at station 1BBVR003.60 for the Water Quality Calibration Period.

In addition to the daily average simulated concentrations presented in the previous figures, a 'five-day window' was considered when performing the water quality calibration. Because the observed values are point-values and represent only an instant in time, it is not reasonable to expect the simulated daily arithmetic mean fecal coliform concentration to exactly match the observed value on a particular day. It is more reasonable to assume that at some point during a window of time surrounding the observed point, the model will simulate a concentration close to that observed. For this reason, we developed a 'five-day window' that considers the minimum and maximum simulated values from the 2 days before to the 2 days after an observed value is collected. We believe it is more reasonable to assume the observed value should fall within this window of simulated values than to assume it will match up with the daily average values presented in the previous figure. The five-day window of simulated values surrounding each observed DEQ sample is presented graphically in Figure 5.4. Seventy-two percent of the observed values fell within their 5-day windows; as can be seen in Figure 5.4, most of those that fell outside the range did not miss it by much.

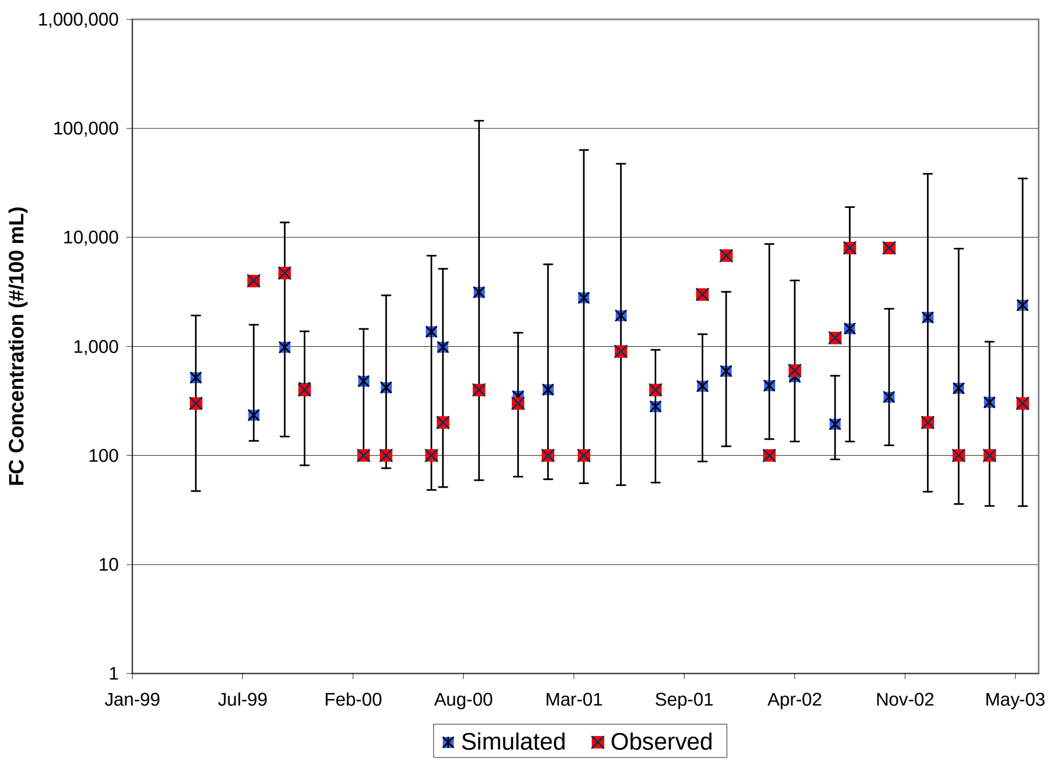

Figure 5.4. 'Five-Day Window' of Simulated Values Surrounding Each Observed DEQ Sample.

The geometric mean of the simulated data for the calibration period is 477 cfu/100 mL; the geometric mean for the observed data for the same period at DEQ station is 480 cfu/100 mL. Because the observed samples were collected on a monthly basis, a comparison of violations of the monthly geometric mean criterion cannot be conducted.

The violation rate of the instantaneous interim fecal coliform water quality standard of 400 cfu/100 mL is 50% for the simulated data for the water quality calibration period. This is very close to the observed 48% violation rate of the 400 cfu/100 mL standard.

The final parameters used in the calibration simulations are listed in Table 5.9 (hydrology) and Table 5.10(water quality).

Table 5.9. Hydrology parameters for Beaver Creek, from Muddy Creek values.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Muddy Creek OR Estimated	Appendix E Table (if applicable)
PERLND						
PWAT-PARM2						
FOREST	Fraction forest cover	none	1.0 forest, 0.0 other	Forest cover	N/A	
LZSN	Lower zone nominal soil moisture storage	inches	8	Soil properties	Muddy Creek	
INFILT	Index to infiltration capacity	in/hr	0.06	Soil and cover conditions	Muddy Creek	
LSUR[**]	Length of overland flow	feet	222-508[a]	Topography	Estimated	1
SLSUR[**]	Slope of overland flowplane	none	0.0062-0.1396[a]	Topography	Estimated	1
KVARY	Groundwater recession variable	1/in	0.0	Calibrate	Muddy Creek	
AGWRC	Base groundwater recession	none	0.99 forest, 0.98 other	Calibrate	Muddy Creek	
PWAT-PARM3						
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	Muddy Creek	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	Muddy Creek	
INFEXP	Exponent in infiltration equation	none	2	Soil properties	Muddy Creek	
INFILD	Ratio of max/mean infiltration capacities	none	2	Soil properties	Muddy Creek	
DEEPFR	Fraction of GW inflow to deep recharge	none	0.3	Geology	Muddy Creek	
BASETP	Fraction of remaining ET from baseflow	none	0.02	Riparian vegetation	Muddy Creek	
AGWETP	Fraction of remaining ET from active GW	none	0	Marsh/wetlands ET	Muddy Creek	
PWAT-PARM4						
CEPSC	Interception storage capacity	inches	monthly[b]	Vegetation	Muddy Creek	3
UZSN	Upper zone nominal soil moisture storage	inches	monthly[b]	Soil properties	Muddy Creek	4
NSUR	Mannings' n (roughness)	none	0.20-0.35[a]	Surface condition	Estimated	2
INTFW	Interflow/surface runoff partition parameter	none	0.75	Soils, topography, land use	Muddy Creek	
IRC	Interflow recession parameter	none	0.40	Soils, topography, land use	Muddy Creek	
LZETP	Lower zone ET parameter	none	monthly[b]	Vegetation	Muddy Creek	5
IMPLND						
IWAT-PARM2						
LSUR	Length of overland flow	feet	300	Topography	Estimated	
SLSUR	Slope of overland flowplane	none	0.01	Topography	Estimated	
NSUR	Mannings' n (roughness)	none	0.1	Surface condition	Estimated	
RETSC	Retention/interception storage capacity	inches	0.065	Surface condition	Muddy Creek	
IWAT-PARM3						
PETMAX	Temp below which ET is reduced	deg. F	40	Climate, vegetation	Muddy Creek	
PETMIN	Temp below which ET is set to zero	deg. F	35	Climate, vegetation	Muddy Creek	
RCHRES						
HYDR-PARM2						
KS	Weighting factor for hydraulic routing		0.3		Muddy Creek	

[**]Calculated from Beaver Creek DEM and land use
[a]Varies with land use
[b]Varies by month and with land use

Table 5.10. Final calibrated water quality parameters for Beaver Creek.

Parameter	Definition	Units	FINAL CALIBRATION	FUNCTION OF…	Appendix E Table (if applicable)
PERLND					
QUAL-INPUT					
SQO	Initial storage of constituent	#/ac	$1x10^{10}$	Land use	
POTFW	Washoff potency factor	#/ton	0		
POTFS	Scour potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	monthly[b]	Land use	6
SQOLIM	Maximum accumulation of constituent	#	9 x ACQOP[b]	Land use	7
WSQOP	Wash-off rate	in/hr	2.5	Land use	
IOQC	Constituent conc. in interflow	#/ft3	8496	Land use	
AOQC	Constituent conc. in active groundwater	#/ft3	5664	Land use	
IMPLND					
QUAL-INPUT					
SQO	Initial storage of constituent	#/ac	$1x10^{7}$		
POTFW	Washoff potency factor	#/ton	0		
ACQOP	Rate of accumulation of constituent	#/day	$1x10^{7}$	Land use	
SQOLIM	Maximum accumulation of constituent	#	$3x10^{7}$	Land use	
WSQOP	Wash-off rate	in/hr	1.0	Land use	
RCHRES					
GQ-GENDECAY					
FSTDEC	First order decay rate of the constituent	1/day	1.15		
THFST	Temperature correction coeff. for FSTDEC		1.05		

[b]Varies by month and with land use

CHAPTER 6: TMDL ALLOCATIONS

The objective of a TMDL is to allocate allowable loads among different pollutant sources so that the appropriate control actions can be taken to achieve water quality standards (USEPA, 1991).

6.1. Bacteria TMDL

6.1.1. Background

The objective of the bacteria TMDL for Beaver Creek was to determine what reductions in fecal coliform and *E. coli* loadings from point and nonpoint sources are required to meet state water quality standards. The state water quality standards for *E. coli* used in the development of the TMDL were 126 cfu/100mL (calendar-month geometric mean) and 235 cfu/100mL (single sample maximum). The TMDL considers all sources contributing fecal coliform and *E. coli* to Beaver Creek. The sources can be separated into nonpoint and point (or direct) sources. The incorporation of the different sources into the TMDL are defined in the following equation:

TMDL = WLA + LA + MOS [6.1]

where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (nonpoint source contributions); and

MOS = margin of safety.

While developing allocation scenarios to implement the bacteria TMDL, an implicit margin of safety (MOS) was used by using conservative estimations of all factors that would affect the bacteria loadings in the watershed (e.g., animal numbers, production rates, and contributions to streams). These factors were estimated in such a way as to represent the worst-case scenario; i.e., these factors would describe the worst stream conditions that could exist in the watershed. Creating a TMDL with these conservative estimates ensures that the worst-case scenario has been considered and that no water quality standard violations will occur if the TMDL plan is followed.

When developing a bacteria TMDL, the required bacteria load reductions are modeled by decreasing the amount of bacteria applied to the land surface; these reductions are presented in the tables in Section 6.1.2b. In the model, this has the effect of reducing the amount of bacteria that reaches the stream, the ultimate goal of the TMDL. Thus, the reductions called for in Section 6.1.2 indicate the need to decrease the amount of bacteria reaching the stream in order to meet the applicable water quality standard. The reductions shown in Section 6.1.2 are not intended to infer that agricultural producers should reduce their herd size, or limit the use of manures as fertilizer or soil conditioner. Rather, it is assumed that the required reductions from affected agricultural source categories (cattle direct deposit, cropland, etc.) will be accomplished by implementing BMPs like filter strips, stream fencing, and off-stream watering; and that required reductions for from residential source categories will be accomplished by repairing aging septic systems, eliminating straight pipe discharges, and other appropriate measures included in the TMDL Implementation Plan.

A period of three years was used for source allocation. Observed meteorological data from the nearby Dale Enterprise weather station were extracted for the period 1989 to 1991 and used in the allocation. This period was selected because it incorporates average rainfall, low rainfall, and high rainfall years; and the climate during this period caused a wide range of hydrologic events including both low and high flow conditions. The dates in all allocation graphs in this report correspond to the 1989-1991 meteorological years; however, the bacteria loadings used in allocation modeling correspond to anticipated future conditions for the Beaver Creek watershed.

The calendar-month geometric mean values used in this report are geometric means of the simulated daily concentrations. Because HSPF was operated with a one-hour time step in this study, 24 hourly concentrations were generated each day. To estimate the calendar-month geometric mean from the hourly HSPF output, we took the arithmetic mean of the hourly values on a daily basis, and then calculated the geometric mean from these average daily values.

The guidance for developing an *E. coli* TMDL offered by VADEQ is to develop input for the model using fecal coliform loadings as the bacteria source in the watershed. Then, VADEQ suggests the use of a translator equation they developed to convert the daily average fecal coliform concentrations output by the model to daily average *E. coli* concentrations (Equation 5.1).

Equation 5.1 was used to convert the fecal coliform concentrations output by HSPF to *E. coli* concentrations. Daily *E. coli* loads were obtained by using the *E. coli* concentrations calculated from the translator equation and multiplying them by the average daily flow. Annual loads were obtained by summing the daily loads and dividing by the number of years in the allocation period.

6.1.2. Beaver Creek Bacteria TMDL

6.1.2.a. Existing Conditions

Analysis of the simulation results for the existing conditions in the watershed (Table 6.1) shows that contributions from pervious land segments are the primary source of *E. coli* in the stream. The results in this table were taken as the average daily contributions for the simulation period, irrespective of the magnitude of the concentration or the flow rate (factors that were considered in the earlier section detailing the source breakdown used in the calibration). Contributions from the upland pervious land segments account for approximately 70% of the concentration at the watershed outlet. Direct deposition of manure by cattle into Beaver Creek is responsible for approximately 16% of the mean daily *E. coli* concentration. The next largest contributors are direct deposits to streams by wildlife (9%), straight pipes (4%), and interflow and groundwater (1%). Runoff from impervious areas contributed almost zero percent of the mean daily *E. coli* concentration.

Table 6.1. Relative contributions of different *E. coli* sources to the overall *E. coli* concentration for the existing conditions in the Beaver Creek watershed.

Source	Mean Daily *E. coli* Concentration by Source, cfu/100mL	Relative Contribution by Source
All Sources	289	
Nonpoint source loadings from pervious land segments	203	70%
Direct deposits of cattle manure to stream	46	16%
Direct nonpoint source loadings to the stream from wildlife	26	9%
Straight-pipe discharges to stream	12	4%
Interflow and groundwater contribution	3	1%
Nonpoint source loadings from impervious land use	≈ 0	≈ 0

The contribution of each of the sources detailed in Table 6.1 to the calendar-month geometric *E. coli* concentration is shown in Figure 6.1. Although there are dates in Figure 6.1, these data should not be compared to other information from that period, as the bacteria loadings used in the model are not for the conditions at that time, but for the conditions expected to be representative of the watershed in the near future. As indicated in this figure, the calendar-month geometric mean value is dominated by contributions from direct deposits of cattle to streams, and these deposits alone result in violations of the calendar-month geometric mean goal of 126 cfu/100mL. Because contributions from upland areas drop during non-runoff conditions between storm events, the contributions from the upland pervious areas to the calendar month geometric mean *E. coli* concentration are much less than their contributions to the daily average concentration. For the same reason, ILS contributions to the calendar month geometric mean concentrations are too small to be represented in Figure 6.1. In-stream *E. coli* concentrations from direct nonpoint sources, particularly cattle in streams, are highest during the summer when stream flows are lowest. This is expected because cattle tend to spend more time in streams during the summer months; because of the low flow conditions, there is less stream flow for dilution of the direct deposit manure load. Straight pipe contributions are significantly lower than the other direct deposit sources in the graph, but due to their constant nature frequently exceed the contributions from PLS sources to the calendar-month geometric mean. Wildlife contributions are maintained rather steadily as a moderate contributor to the geometric mean.

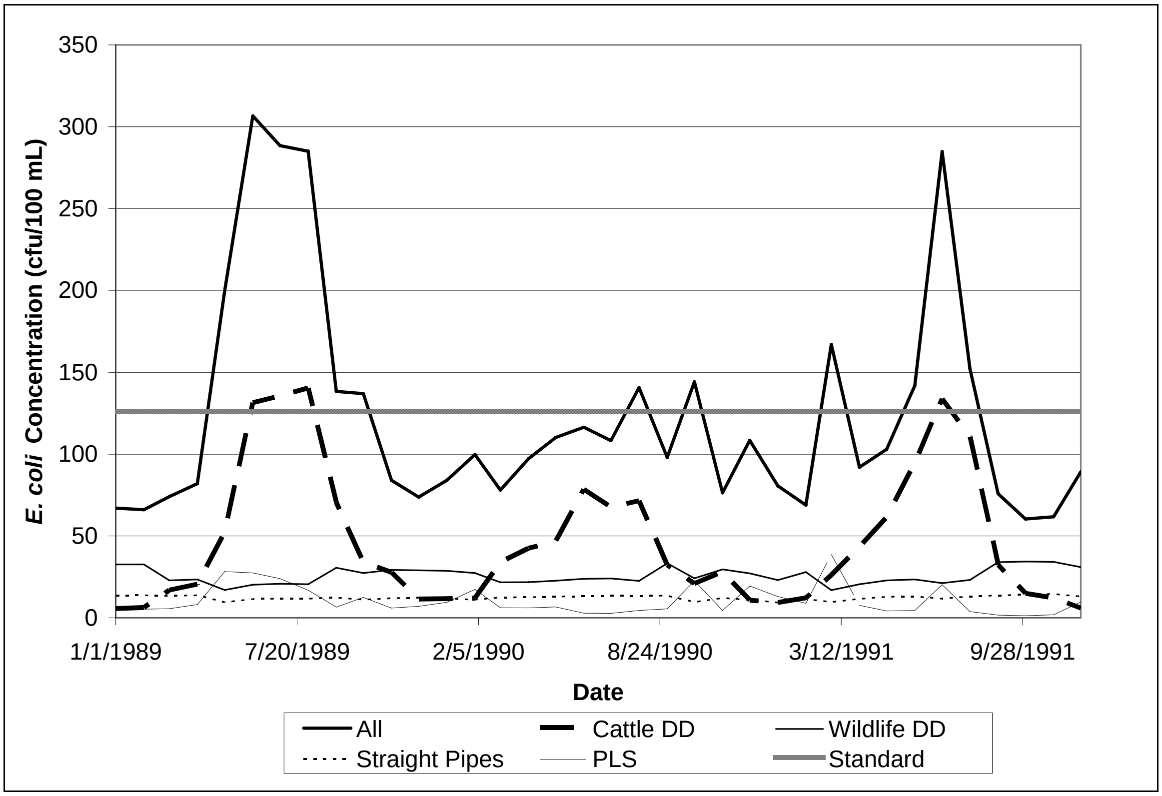

Figure 6.1. Relative contributions of different *E. coli* sources to the calendar-month geometric mean *E. coli* concentration for existing conditions in the Beaver Creek watershed.

<u>6.1.2.b. Allocation Scenarios</u>

The spring flow originating in sub-watershed BVR-04 is a major contributor to flow in the watershed. On average, spring flow accounts for well over two-thirds of the flow from the entire watershed. The flow from the spring has a significant impact on water quality within the stream segments to which it contributes. Water quality samples taken from the spring show minimal to nondetectable levels of bacteria in the spring water. This relatively clean volume of water dilutes the flow coming from Waggys Creek, which results in reduced bacteria concentrations downstream of the Beaver Creek/Waggys Creek confluence. In order to ensure standards compliance at both the ambient monitoring station and the watershed outlet, the Beaver Creek watershed was divided into two segments: Waggys Creek in the upstream area and Lower Beaver Creek in the downstream area; allocation scenarios were generated for both segments. The upper sub-division is the drainage area of Waggys Creek down to the confluence with Beaver Creek (sub-watershed numbers 5-11). The lower sub-division is the remainder of the Beaver Creek watershed (sub-watersheds 1-4) – these were presented graphically in Section 3.2, Figure 3.3.

A variety of allocation scenarios were evaluated to meet the *E. coli* TMDL goal of a calendar-month geometric mean of 126 cfu/100mL and the single sample limit of 235 cfu/100mL. The scenarios and results are summarized in Table 6.2 and Table 6.3; recall that these reductions are those used for modeling, and implementation of these reductions will require implementation of BMPs as discussed at the beginning of this chapter. One successful scenario was found for the Waggys Creek portion of the watershed. Two scenarios met the standards at Lower Beaver Creek outlet. All numbered scenarios presented in Table 6.3 for Lower Beaver Creek include the successful load reductions (Scenario W3) from Waggys Creek applied to the Waggys Creek area; the reductions listed in Table 6.3 were then applied to the Lower Beaver Creek area.

Table 6.2. Bacteria allocation scenarios for the Waggys Creek watershed.

Scenario Number	% Violation of *E. coli* standard		Required Fecal Coliform Loading Reductions to Meet the *E coli* Standards,%					
	Geomean	Single Sample	Cattle DD	Loads from Cropland	Loads from Pasture	Wildlife DD	Straight Pipes	Loads from Residential
Existing Conditions	100%	56%	0	0	0	0	0	0
W1	33%	5%	100	100	100	0	100	100
W2	28%	0%	100	100	100	20	100	100
W3	0%	0%	100	100	100	50	100	100

Table 6.3. Bacteria allocation scenarios for the Lower Beaver Creek watershed.

Scenario Number	% Violation of *E. coli* standard		Required Fecal Coliform Loading Reductions to Meet the *E coli* Standards,%					
	Geomean	Single Sample	**Cattle DD**	**Loads from Cropland**	**Loads from Pasture**	**Wildlife DD**	**Straight Pipes**	**Loads from Residential**
Existing Conditions*	33%	11%	0	0	0	0	0	0
B1	0.0%	8%	50	0	0	0	100	0
B2	0.0%	1%	50	30	95	0	100	0
B3	0.0%	0.1%	100	20	100	0	100	0
B4	0.0%	0.0%	100	50	99	0	100	0
B5	0.0%	0.0%	0	30	100	0	100	0

*Includes no reductions in Lower Beaver Creek or Waggys Creek

As can be seen from the Existing Conditions in Table 6.2, the initial violation rate for the geometric mean standard for Waggys Creek was extreme. Elimination of all anthropogenic sources (Scenario W1) still resulted in a 33% violation rate of this standard. The direct deposit from wildlife in the low flow volumes of Waggys Creek caused these violations. Scenario W3 was the only successful allocation scenario for Waggys Creek. The concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 6.2 for the TMDL allocation (Scenario W3), along with the standards.

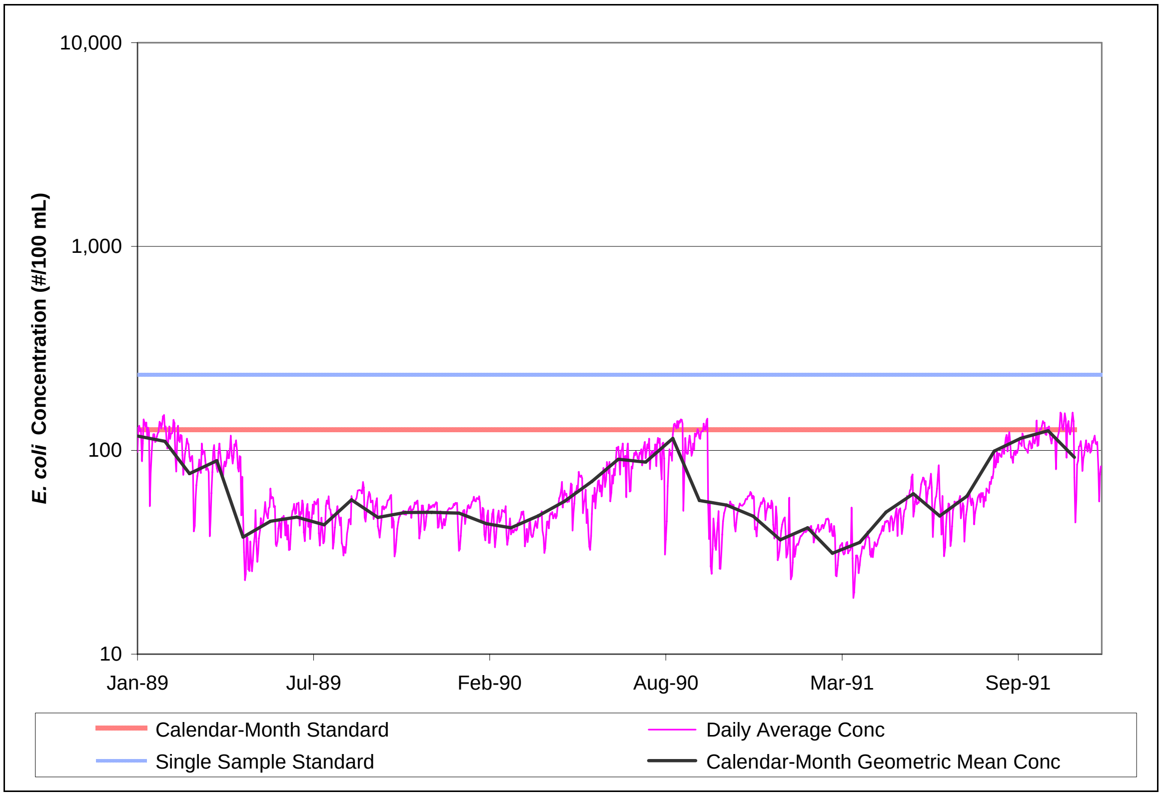

Figure 6.2. Calendar-month geometric mean standard, single sample standard, and successful *E. coli* TMDL allocation (Allocation Scenario W3) for Waggys Creek watershed.

The Existing Conditions in Table 6.3 for Lower Beaver Creek were much less extreme than those in Waggys Creek, at 33% violation of the geometric mean standard and 11% violation of the instantaneous standard. This is due to the dilution effect of the spring. In scenario B1 for Lower Beaver Creek, straight pipes were eliminated and large reductions (50%) were taken from direct deposition of cattle in the streams. This had a significant effect, eliminating the violations of the geometric mean standard and reducing the violation of the instantaneous standard by 3%. Reducing contributions from cropland and pasture (scenario B2) dropped the instantaneous violation rate another 7%. As can be seen from scenario B3, a small increase in loading reductions from pasture more than compensates for a larger decrease in loading reductions from cropland. Thus, the successful allocation scenarios (B4 and B5) require higher reductions from pasture, and lower reductions from other sources. The lack of a requirement for direct deposit reductions from cattle in Scenario B5 is due to the dilution effect of the spring – this reduces the contributions of direct deposit loadings to standards violations. Many cattle have already been fenced from the stream in Lower Beaver Creek. Because there is always a substantial flow in Lower Beaver Creek, the bacteria load from the remaining cattle do not create a high enough concentration to violate the water quality standards under baseflow conditions. However, the high concentrations of bacteria transported to the stream from pasture areas during runoff events do cause standards violations. Because the loading from cattle direct deposit has a small effect on the in-stream concentration in Lower Beaver Creek during higher flow runoff periods when the standard is violated, a 100% cattle direct deposit reduction is required in scenario B4 in order to compensate for a less than 100% load reduction from pasture areas.

Scenarios B4 and B5 both meet both *E. coli* standards and would be acceptable targets for implementation. Because Scenario B5 is less restrictive than B4, the calculated TMDL loads and associated graphs and tables in this report are for Scenario B5. This scenario requires no reductions from cattle stream access, wildlife, or residential areas in the Lower Beaver Creek watershed. The concentrations for the calendar-month and daily average *E. coli* values are shown in Figure 6.3 for the TMDL allocation (Scenario B5), along with the standards. During implementation planning, the implementation plan steering committee could choose either successful scenario upon notification to EPA.

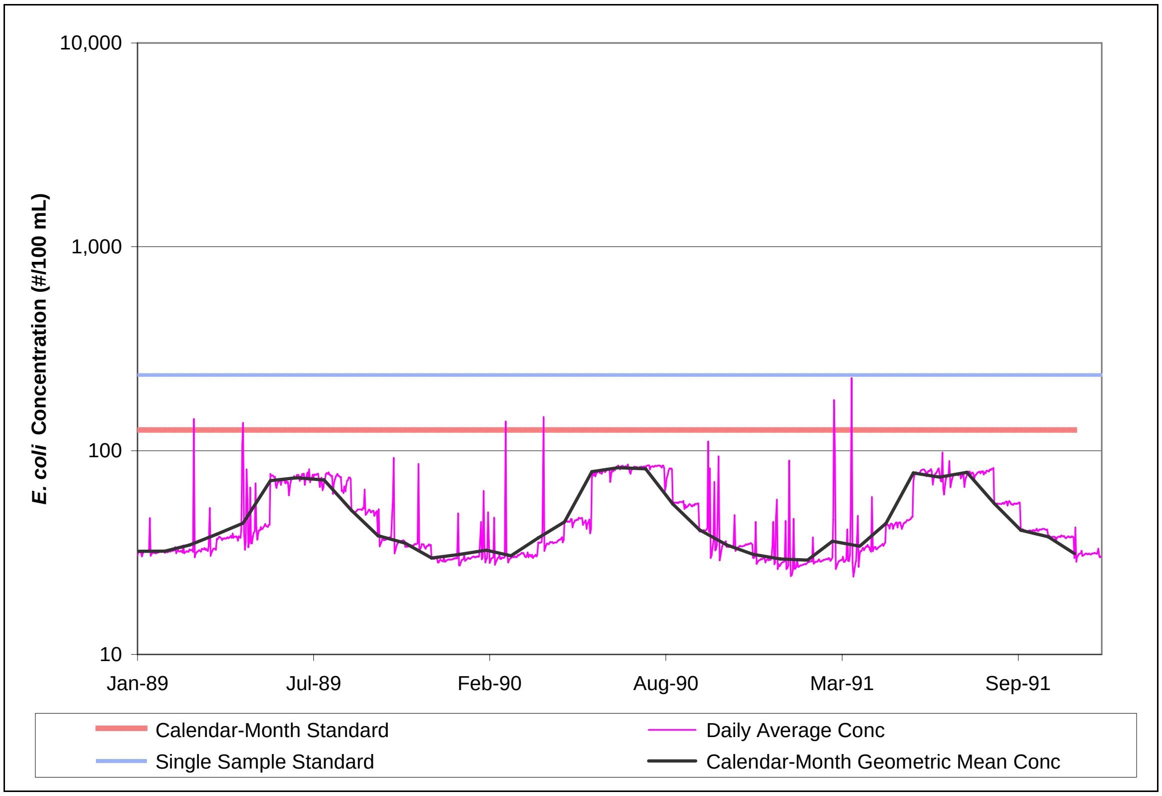

Figure 6.3. Calendar-month geometric mean standard, single sample standard, and successful *E. coli* TMDL allocation (Allocation Scenario B5) for Lower Beaver Creek watershed (outlet of main watershed).

Loadings for existing conditions and the TMDL allocation scenario (Scenarios W3&B5) are presented for nonpoint sources by land use in Table 6.4 and for direct nonpoint sources in Table 6.5. It is clear that extreme reductions in both loadings from land surfaces and from sources directly depositing in the streams of Waggys Creek (Table 6.2) are required to meet both the calendar-month geometric mean and single sample standards for *E. coli*. The diluted flow of Lower Beaver Creek means no reductions are called for in direct deposits from animals, but the very high pasture loadings shown in Table 6.4 must be reduced to prevent violations of the instantaneous standard during storm events.

Table 6.4. Annual nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation scenario W3/B5.

Land use Category	Watershed Fragment	Existing Conditions		Allocation Scenario	
		Existing conditions load (× 10^{12} cfu/yr)	Percent of total land deposited load from nonpoint sources	TMDL nonpoint source allocation load (× 10^{12} cfu/yr)	Percent reduction from existing load
Cropland	Waggys	23	<1%	0	100%
	Lower Beaver	133	1%	93	30%
Pasture	Waggys	7,451	44%	0	100%
	Lower Beaver	9,092	54%	0	100%
Residential[a]	Waggys	81	<1%	0	100%
	Lower Beaver	121	1%	121	0%
Forest	Waggys	58	<1%	58	0%
	Lower Beaver	9	<1%	9	0%
Total	Waggys	7,613	45%	58	99%
	Lower Beaver	9,355	55%	224	98%
	All	16,968	100%	282	98%

[a] Includes loads applied to both High and Low Density Residential and Farmstead

Table 6.5. Annual direct nonpoint source fecal coliform loads under existing conditions and corresponding reductions for TMDL allocation for scenario W3/B5.

Source	Watershed Fragment	Existing Condition		Allocation Scenario	
		Existing conditions load (× 10^{12} cfu/yr)	Percent of total direct deposited load from direct nonpoint sources	TMDL direct nonpoint source allocation load (× 10^{12} cfu/yr)	Percent reduction
Cattle in streams	Waggys	22	32%	0	100%
	Lower Beaver	11	16%	11	0%
Straight Pipes	Waggys	3	4%	0	100%
	Lower Beaver	19	27%	0	100%
Wildlife in Streams	Waggys	9	13%	4	50%
	Lower Beaver	6	8%	6	0%
Total	Waggys	34	49%	4	87%
	Lower Beaver	35	51%	17	53%
	All	69	100%	21	70%

The fecal coliform loads presented in Table 6.4 and Table 6.5 are the fecal coliform loads that result in in-stream *E coli* concentrations that meet the applicable *E coli* water quality standards after application of the VADEQ fecal coliform to *E coli* translator to the HSPF predicted mean daily fecal coliform concentrations.

9.1.2.c. Waste Load Allocation

Waste load allocations were assigned to the seven point source facilities located in the Beaver Creek watershed (Table 6.6). The point sources were represented in the allocation scenarios by their current permit conditions; no reductions were required from the point sources in the TMDL. Current permit requirements are expected to result in attainment of the *E. coli* WLA as required by the TMDL. Point source contributions, even in terms of maximum flow, are minimal. Therefore, no reasonable potential exists for these facilities to have a negative impact on water quality and there is no reason to modify the existing permits. The point source facilities are discharging at their criteria and therefore cannot cause a violation of the water quality criteria.

Table 6.6. Point Sources Discharging Bacteria in the Beaver Creek Watershed.

Permit Number	Flow (gpd)	Permitted FC Conc. (cfu/100 mL)	Permitted FC Load (cfu/year)	Allocated FC Load (cfu/year)	Allocated *E. coli* Load (cfu/year)
VAG401004	1000	200	$2.76*10^9$	$2.76*10^9$	$1.74*10^9$
VAG401143	1000	200	$2.76*10^9$	$2.76*10^9$	$1.74*10^9$
VAG401144	1000	200	$2.76*10^9$	$2.76*10^9$	$1.74*10^9$
VAG401478	1000	200	$2.76*10^9$	$2.76*10^9$	$1.74*10^9$
VAG401599	1000	200	$2.76*10^9$	$2.76*10^9$	$1.74*10^9$
VAG401679	1000	200	$2.76*10^9$	$2.76*10^9$	$1.74*10^9$
VAG408022	1000	200	$2.76*10^9$	$2.76*10^9$	$1.74*10^9$

9.1.2.d. Summary of Beaver Creek's TMDL Allocation Scenario for Bacteria

A TMDL for *E. coli* has been developed for Beaver Creek. The TMDL addresses the following issues:

1. The TMDL meets the calendar-month geometric mean and single sample water quality standards.
2. Because *E. coli* loading data were not available to quantify point or nonpoint source bacterial loads, available fecal coliform loading data were used as input to HSPF. HSPF was then used to simulate in-stream fecal

coliform concentrations. The VADEQ fecal coliform to *E. coli* concentration translator was then used to convert the simulated fecal coliform concentrations to *E. coli* concentrations for which the bacteria TMDL was developed.

3. The TMDL was developed taking into account all fecal bacteria sources (anthropogenic and natural) from both point and nonpoint sources.
4. An implicit margin of safety (MOS) was incorporated by utilizing professional judgment and conservative estimates of model parameters.
5. Both high- and low-flow stream conditions were considered while developing the TMDL. In the Beaver Creek watershed, low stream flow was found to be the environmental condition most likely to cause a violation of the geometric mean criterion; however, because the TMDL was developed using a continuous simulation model, it applies to both high- and low-flow conditions. Violations of the instantaneous criterion were associated primarily with storm flows.
6. Both the flow regime and bacteria loading to Beaver Creek are seasonal. The TMDL accounts for these seasonal effects.
7. In order to ensure compliance at the watershed outlet and at the ambient monitoring station 1BBVR003.60, the watershed was divided into two segments for allocation purposes. This divide occurred at the confluence of Waggys Creek and Beaver Creek.

The selected *E. coli* TMDL allocation that meets both the calendar-month geometric mean and single sample water quality goals requires 100% reductions in anthropogenic sources and a 50% reduction in wildlife direct deposits in the Waggys Creek portion of the watershed. The allocation scenario for the lower segment of the watershed (Lower Beaver Creek watershed) called for no reduction in cattle or wildlife direct deposition of manure to streams. It did call for elimination of all unpermitted straight-pipe discharges, a 100% reduction in nonpoint source loadings to pasture, and a 30% reduction in nonpoint source loadings to cropland. Using Eq. [6.1], the summary of the bacteria TMDL for

Beaver Creek for the selected allocation scenario (Scenario W3/B5) is given in Table 6.7. In Table 6.7, the WLA was obtained by multiplying the permitted point source's fecal coliform discharge concentration by its allowable annual discharge. The LA is then determined as the TMDL – WLA.

Table 6.7. Annual *E. coli* loadings (cfu/year) at the watershed outlet used for the Beaver Creek bacteria TMDL.

Parameter	ΣWLA	ΣLA	MOS[a]	TMDL
E. coli	1.22×10^{10} *(Σ 7 general permits=1.22×10^{10})*	$1{,}567 \times 10^{10}$	--	$1{,}568 \times 10^{10}$

[a]Implicit MOS

CHAPTER 7: TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

7.1. TMDL Implementation Process

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairment on Beaver Creek. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels in the stream. These measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the recent "TMDL Implementation Plan Guidance Manual" (VADCR and VADEQ, 2003), published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource. Additionally, development of an approved implementation plan will improve a locality's chances for obtaining financial and technical assistance during implementation.

7.2. Staged Implementation

In general, Virginia intends for the required reductions to be implemented in an iterative process that first addresses those sources with the greatest impact on water quality. For example, in agricultural areas of the watershed, the most promising best management practice to address the bacteria TMDL is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers. Although no cattle direct-deposit reductions are called for in the Lower Beaver Creek watershed, this second benefit of livestock exclusion from streams will still be crucial in reducing the large bacteria loadings from pasture.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following Stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

7.3. Stage 1 Scenarios

The goal of the Stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the instantaneous criterion (235 cfu/100mL) are less than 10 percent. The Stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios.

Similarly to the TMDL scenarios, Stage 1 scenarios were developed for both Waggys Creek and Lower Beaver Creek. The successful scenarios for Waggys Creek watershed were scenarios W3 and W4 in Table 7.1. Stage 1 scenarios were developed for Lower Beaver Creek using scenarios W3 and W4 on the Waggys Creek portion of the watershed. The successful scenarios for Stage 1 for the Lower Beaver Creek watershed are shown in Table 7.2. The reductions called for in the Lower Beaver Creek watershed are identical for both upstream scenarios (Table 7.2). With the upstream reductions of Table 7.1 in place, elimination of straight pipes in the downstream watershed in both cases will reduce the bacteria levels to those required for Stage 1 implementation. Both combinations of scenarios are viable options for Stage 1 implementation and the final decision is left to the stakeholders. Scenarios for the entire watershed require elimination of straight pipe dischargers. Scenarios for Waggys Creek additionally require large reductions in cattle direct deposits to the stream and loadings from pasture. None of the Stage 1 scenarios require reductions from wildlife. Based on the existing condition loads in Table 6.4, Stage 1 scenario W3/B1 will require 42% reduction in total loads to the land surface; scenario W4/B2 will require 43% reduction in total loads to the land surface. Based on the existing condition direct nonpoint source loadings in Table 6.5, Stage 1 scenario W3/B1 will require 59% reduction in total nonpoint loads to the stream; scenario W4/B2 will require 56% reduction in total nonpoint loads to the stream. *E. coli* concentrations resulting from application of the fecal coliform to *E.*

coli translator equation to the Stage 1 fecal coliform loads are presented graphically in Figure 7.1, Figure 7.2, Figure 7.3, and Figure 7.4.

Table 7.1. Allocation scenarios for Stage 1 TMDL implementation for Waggys Creek watershed.

Scenario Number	Single Sample Standard % Violation	% Reduction Required					
		Cattle DD	Cropland	Pasture	Wildlife DD	Straight Pipes	All Residential PLS
W1	9	100	0	95	0	100	0
W2	13	75	0	99	0	100	0
W3	10	90	0	95	0	100	0
W4	10	81	0	99	0	100	0

Table 7.2. Allocation scenarios for Stage 1 TMDL implementation for Lower Beaver Creek watershed.

Scenario Number	Single Sample % Violation	% Reduction Required					
		Cattle DD	Cropland	Pasture	Wildlife DD	Straight Pipes	All Residential PLS
B1 (based on W3)	9	0	0	0	0	100	0
B2 (based on W4)	9	0	0	0	0	100	0

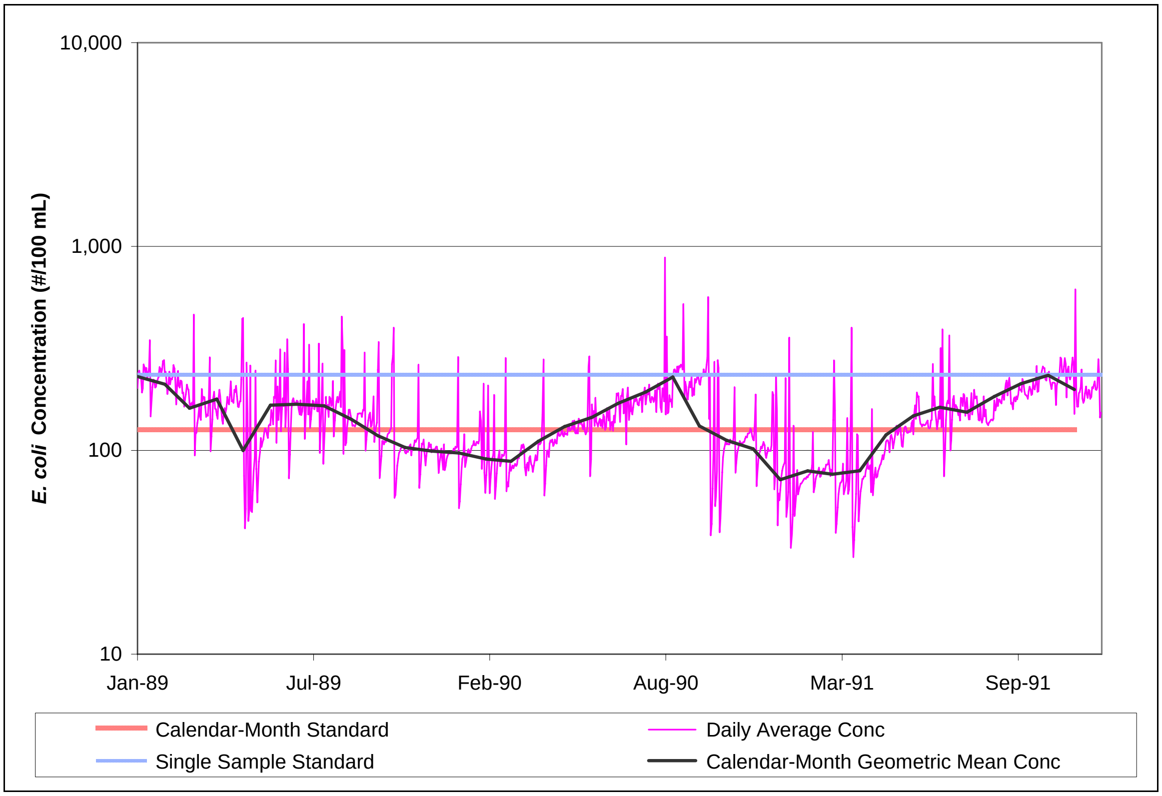

Figure 7.1. Stage 1 TMDL implementation scenario at station 1BBVR003.60 for scenario W3/B1.

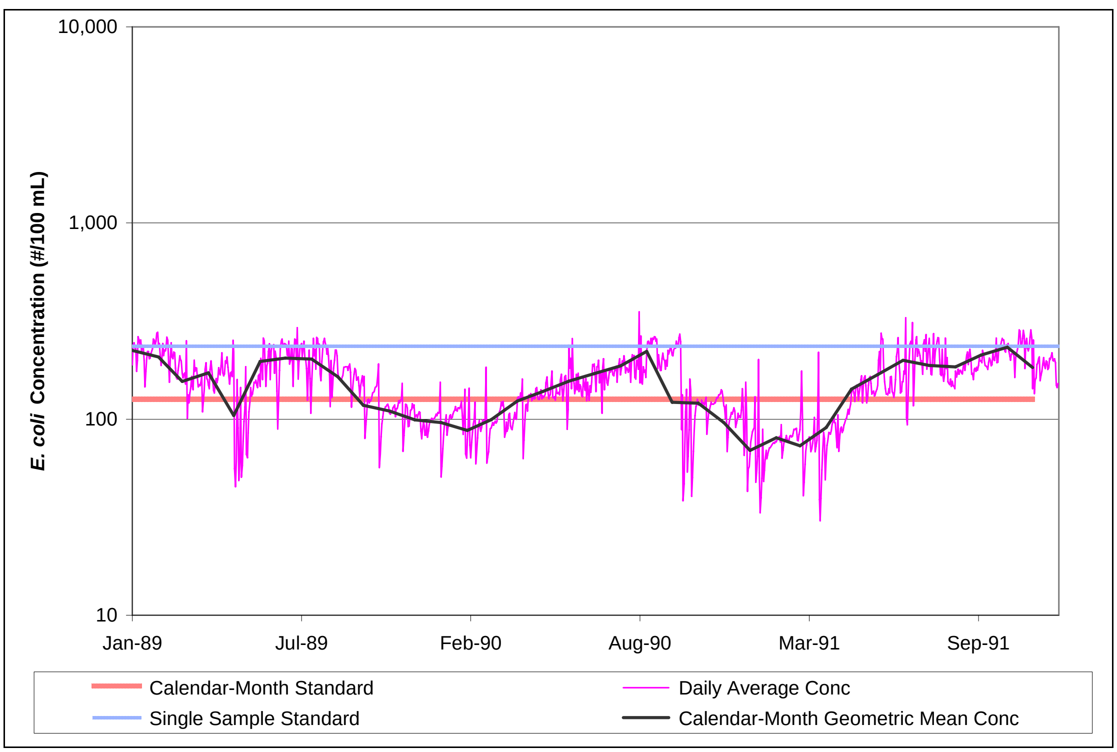

Figure 7.2. Stage 1 TMDL implementation scenario at station 1BBVR003.60 for scenario W4/B2.

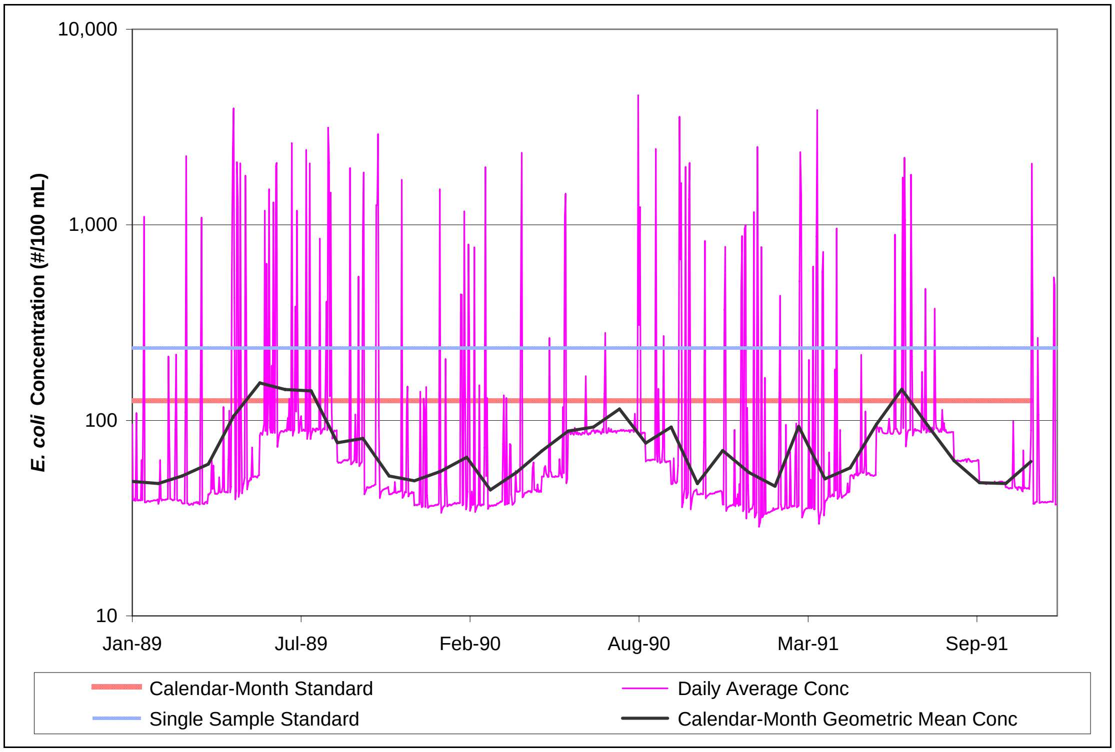

Figure 7.3. Stage 1 TMDL implementation scenario at the watershed outlet for scenario W3/B1.

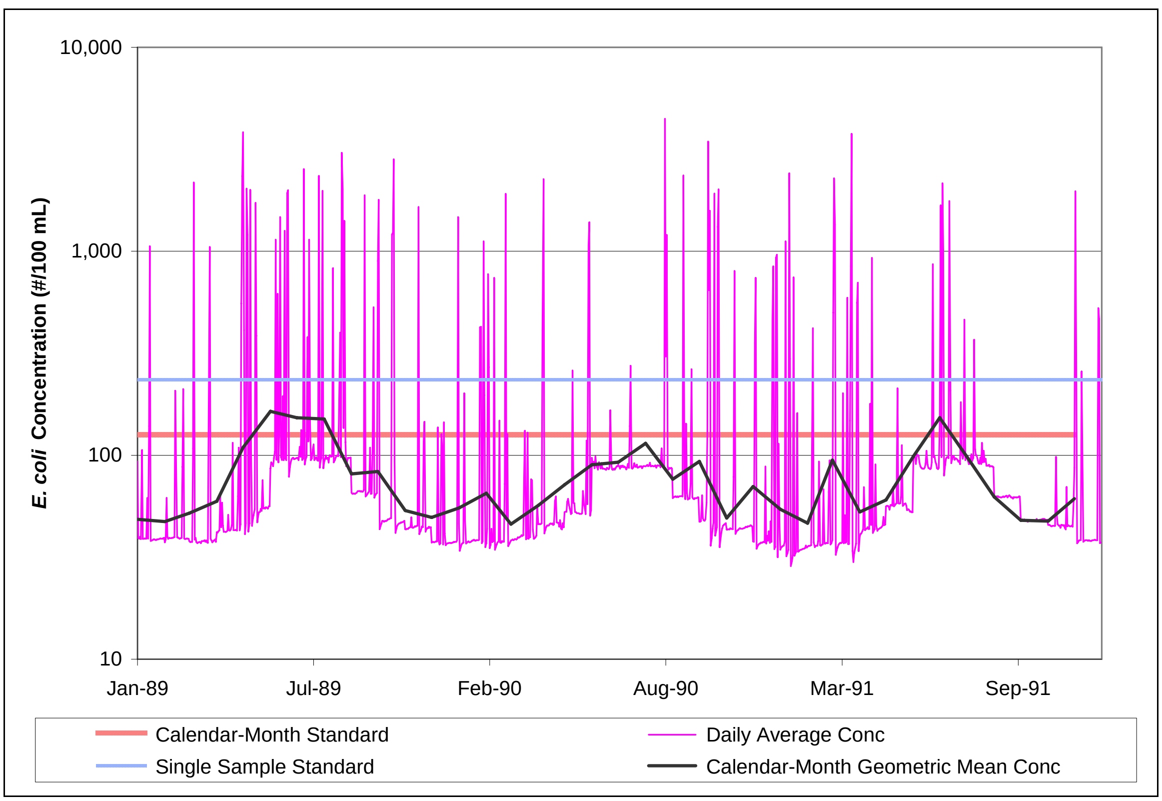

Figure 7.4. Stage 1 TMDL implementation scenario at the watershed outlet for scenario W4/B2.

7.4. Link to ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the Chesapeake Bay. Several BMPs known to be effective in controlling bacteria have been identified for implementation as part of the Commonwealth of Virginia Shenandoah and Potomac River Basins Tributary Nutrient Reduction Strategy. For example, management of on-site waste management systems, management of livestock and manure, and pet waste management are among the components of the strategy described under nonpoint source implementation mechanisms (VASNR, 1996). A new tributary strategy is currently being developed for the Shenandoah-Potomac River Basin to address the nutrient and sediment reductions required to restore the health of the Chesapeake Bay. Up-to-date information can be found at the tributary strategy web site under http://www.snr.state.va.us/Initiatives/TributaryStrategies/shenandoah.cfm.

7.5. Reasonable Assurance for Implementation

7.5.1. Follow-up Monitoring

VADEQ will continue monitoring Beaver Creek (1BBVR003.60) in accordance with its ambient monitoring programs to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards.

7.5.2. Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

7.5.3. Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Nonpoint Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

7.5.4. Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new “secondary contact” category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for “secondary contact recreation” which means “a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)”. These new criteria were approved by the USEPA and became effective in February 2004. Additional information on the action by the triennial review can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/pdf/WQS04.pdf.

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a Stage 1 implementation scenario (presented earlier in this chapter). The pollutant reductions in the Stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the Stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

CHAPTER 8: PUBLIC PARTICIPATION

Public participation was elicited at every stage of the TMDL development in order to receive inputs from stakeholders and to apprise the stakeholders of the progress made. In October of 2004, members of the Virginia Tech TMDL group traveled to Rockingham County to become acquainted with the watershed. During that trip, they spoke with various stakeholders. In addition, personnel from Virginia Tech contacted stakeholders via telephone to acquire their input.

The first public meeting was held on September 22, 2004 at the Ottobine Elementary school in Dayton, Virginia to inform the stakeholders of TMDL development process. Approximately 30 people attended the meeting.

Two local steering committee meetings were held after the first public meeting. This committee consisted of a group of interested stakeholders for the watershed. During the first local steering committee meeting on October 25, 2004 at the DEQ office in Harrisonburg, the committee members provided feedback on and refinement of the human and animal numbers used in modeling. During the second meeting on February 22, 2005, also located at the DEQ office, the committee members provided feedback on the water quality calibration. Seven stakeholders attended the first meeting and six attended the second meeting. At each of these meetings, the attendees received a packet of information containing details on the topic of discussion.

The final public meeting was held on July 12, 2005 at the Ottobine Elemenary School in Dayton, Virginia to present the draft TMDL report and solicit comments from stakeholders. Approximately 17 stakeholders attended the final meeting. Copies of the presentation materials and the executive summary of this report were distributed to the public at the meeting. The public comment period ended on August 12, 2005.

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APPENDIX A.
Glossary of Terms

Glossary of Terms

Allocation

That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources.

Allocation Scenario

A proposed series of point and nonpoint source allocations (loadings from different sources), which are being considered to meet a water quality planning goal.

Background levels

Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering and dissolution.

BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)

A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.

Best Management Practices (BMP)

Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.

Bacteria Source Tracking

A collection of scientific methods used to track sources of fecal coliform.

Calibration

The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.

Die-off (of fecal coliform)

Reduction in the fecal coliform population due to predation by other bacteria as well as by adverse environmental conditions (e.g., UV radiation, pH).

Direct nonpoint sources

Sources of pollution that are defined statutorily (by law) as nonpoint sources that are represented in the model as point source loadings due to limitations of the model. Examples include: direct deposits of fecal material to streams from livestock and wildlife.

E-911 digital data

Emergency response database prepared by the county that contains graphical data on road centerlines and buildings. The database contains approximate outlines of buildings, including dwellings and poultry houses.

Failing septic system

Septic systems in which drain fields have failed such that effluent (wastewater) that is supposed to percolate into the soil, now rises to the surface and ponds on the surface where it can flow over the soil surface to streams or contribute pollutants to the surface where they can be lost during storm runoff events.

Fecal coliform

A type of bacteria found in the feces of various warm-blooded animals that is used as indicator of the possible presence of pathogenic (disease causing) organisms.

Geometric mean

The geometric mean is simply the nth root of the product of n values. Using the geometric mean, lessens the significance of a few extreme values (extremely high or low values). In practical terms, this means that if you have just a few bad samples, their weight is lessened.

Mathematically the geometric mean, $\overline{x}_g$, is expressed as:

$$\overline{x}_g = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \ldots \cdot} x_n$$

where n is the number of samples, and x_i is the value of sample i.

HSPF (Hydrological Simulation Program-Fortran)

A computer-based model that calculates runoff, sediment yield, and fate and transport of various pollutants to the stream. The model was developed under the direction of the U.S. Environmental Protection Agency (EPA).

Hydrology

The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Instantaneous criterion

The instantaneous criterion or instantaneous water quality standard is the value of the water quality standard that should not be exceeded at any time. For example, the Virginia instantaneous water quality standard for fecal coliform is 1,000 cfu/100 mL. If this value is exceeded at any time, the water body is in violation of the state water quality standard.

Load allocation (LA)

The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background.

Margin of Safety (MOS)

A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody. The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models). The MOS may also be assigned explicitly, as was done in this study, to ensure that the water quality standard is not violated.

Model

Mathematical representation of hydrologic and water quality processes. Effects of Land use, slope, soil characteristics, and management practices are included.

Nonpoint source

Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.

Pathogen

Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.

Point source

Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.

Pollution

Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.

Reach

Segment of a stream or river.

Runoff

That part of rainfall or snowmelt that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.

Septic system

An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives liquid and solid wastes from a residence or business and a drainfield or subsurface absorption system consisting of a series of tile or percolation lines for disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.

Simulation

The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.

Straight pipe

Delivers wastewater directly from a building, e.g., house, milking parlor, to a stream, pond, lake, or river.

Total Maximum Daily Load (TMDL)

The sum of the individual wasteload allocations (WLA's) for point sources, load allocations (LA's) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.

Urban Runoff

Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model)

Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.

Wasteload allocation (WLA)

The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation.

Water quality standard

Law or regulation that consists of the beneficial designated use or uses of a water body, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular water body, and an anti-degradation statement.

Watershed

A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

For more definitions, see the Virginia Cooperative Extension publications available online:

Glossary of Water-Related Terms. Publication 442-758.
http://www.ext.vt.edu/pubs/bse/442-758/442-758.html

and

TMDLs (Total Maximum Daily Loads) - Terms and Definitions. Publication 442-550.
http://www.ext.vt.edu/pubs/bse/442-550/442-550.html

APPENDIX B.
Sample Calculation of Cattle
(Sub-Watershed BVR-02)

Sample Calculation: Distribution of Cattle

(Sub-watershed (BVR-02) during January)

(Note: Due to rounding, the numbers may not add up.)

There are 180 beef cows in sub-watershed 02.

1. During January, beef cattle are confined 75% of the time (Table 4.5).
   Beef cattle in confinement = 180 * (40%) = 72
2. When not confined, cattle are on the pasture or in the stream.
   Beef cattle on pasture and in the stream = (180 – 72) = 108
3. Twelve percent of the pasture acreage has stream access (Table 4.6). Hence beef cattle with stream access are calculated as:
   Beef cattle on pastures with stream access = 108 * (12%) = 13
4. Beef cattle in and around the stream are calculated using the numbers in Step 3 and the number of hours cattle spend in the stream in January (Table 4.6) as:
   Beef cattle in and around streams = 13 * (0.5/24) = 0.27
5. Number of cattle defecating in the stream is calculated by multiplying the number of cattle in and around the stream by 30% (Section 0)
   Beef cattle defecating in streams = 0.27 * (30%) = 0.08
6. After calculating the number of cattle defecating in the stream, the number of cattle defecating on the pasture is calculated by subtracting the number of cattle defecating in the stream (Step 5) from number of cattle in pasture and stream (Step 2).
   Beef cattle defecating on pasture = (108 – 0.08) = 107.92

Now, obviously there is not 8/100th of a cow standing and defecating in the stream. This number represents the fraction of fecal coliform produced in one day by one cow that will be deposited in the stream.

APPENDIX C.
Die-off Fecal Coliform During Storage

Die-off of Fecal Coliform During Storage

The following procedure was used to calculate amount of fecal coliform produced in confinement in dairy manure applied to cropland and pasture. All calculations were performed on spreadsheet for each sub watershed with dairy operations in a watershed.

1. It was determined from a producer survey in Rockingham County that 15% of the dairy farms had dairy manure storage for less than 30 days; 10% of the dairy farms had storage capacities of 60 days, while the remaining operations had 180-day storage capacity. Using a decay rate of 0.375 for liquid dairy manure, the die-off of fecal coliform in different storage capacities at the ends of the respective storage periods were calculated using Eq. [5.1]. Based on the fractions of different storage capacities, a weighted average die-off was calculated for all dairy manure.
2. Based on fecal coliform die-off, the surviving fraction of fecal coliform at the end of storage period was estimated to be 0.0078 in dairy manure.
3. The annual production of fecal coliform based on 'as-excreted' values was calculated for dairy manure.
4. The annual fecal coliform production from dairy manure was multiplied by the fraction of surviving fecal coliform to obtain the amount of fecal coliform that was available for land application on annual basis. For monthly application, the annual figure was multiplied by the fraction of dairy applied during that month based on the application schedule given in Table 4.9.

APPENDIX D.
Weather Data Preparation

Weather Data Preparation

A weather data file for providing the weather data inputs into the HSPF Model was created for the period using WDMUtil. Raw data required for creating the weather data file included hourly precipitation (in.), average daily temperatures (maximum, minimum, and dew point) (°F), average daily wind speed (mi./h), total daily solar radiation (langleys), and percent sun. The primary data source for most parameters was the National Climatic Data Center's (NCDC) Cooperative Weather Station at Dale Enterprise, Rockingham Co., Virginia; data from three other NCDC stations were also used. Locations and data periods from the stations used are listed in Table D-1. Daily solar radiation data was generated using WDMUtil. The raw data required varying amounts of preprocessing prior to input into WDMUtil or within WDMUtil to obtain the following hourly values: precipitation (PREC), air temperature (ATEM), dew point temperature (DEWP), solar radiation (SOLR), wind speed (WIND), potential evapotranspiration (PEVT), potential evaporation (EVAP), and cloud cover (CLOU). The final WDM file contained the above hourly values as well as the raw data. Weather data in the variable length format were obtained from the NCDC's weather stations in Dale Enterprise, VA (Lat./Long. 38.5N/78.9W, elevation 1400 ft); Lynchburg Airport, VA (Lat./Long. 37.3N/79.2W, elevation 940 ft); and Elkins Airport, WV (Lat./Long. 38.9N/79.9W, elevation 1948 ft). While deciding on the period of record for the weather WDM file, availability of flow and water quality data was considered in addition to the availability and quality of weather data.

Table D.1. Meteorological data sources.

Type of Data	Location	Source	Recording Frequency	Period of Record	Latitude Longitude
Rainfall (in)	Dale Enterprise	NCDC	1 Hour 1 Day	1/1/73 - present 9/1/48 - present	38°10’52” 79°05’25”
Min Air Temp (°F)	Staunton Sewage Treatment Plant	NCDC	1 Day	8/1/48 - present	38°10’52” 79°05’25”
Max Air Temp (°F)	Staunton Sewage Treatment Plant	NCDC	1 Day	8/1/48 - present	38°10’52” 79°05’25”
Min Air Temp (°F)	Dale Enterprise	NCDC	1 Day	1/1/48 - present	38°27’19” 78°56’07”
Max Air Temp (°F)	Dale Enterprise	NCDC	1 Day	1/1/48 - present	38°27’19” 78°56’07”
Cloud Cover (%)	Lynchburg Regional Airport	NCDC	1 Day	1/1/65 - 7/31/96	37°20’15” 79°12’24”
Dew Point Temp (°F)	Elkins Airport, WV	NCDC	1 Day	1/1/48 - present	37°20’15” 79°12’24”
Wind Speed (360° and knots)	Elkins-Randolph Elkins WV	NCDC	1 Day	1/1/84 - present	38°53’07” 79°51’10”

APPENDIX E.
HSPF Parameters that Vary by Month or Land Use

Table E1. PWAT-PARM2 parameters that vary by land use for Beaver Creek.

Landuse_Sub	LSUR	SLSUR		Landuse_Sub	LSUR	SLSUR
	(ft)				(ft)	
Cropland_1	502	0.0093		LDR_2	471	0.0233
Cropland_2	429	0.0432		LDR_3	502	0.0091
Cropland_3	493	0.0131		LDR_4	466	0.0259
Cropland_4	407	0.0536		LDR_7	492	0.0138
Cropland_5	432	0.0416		LDR_9	391	0.0611
Cropland_6	435	0.0402		LDR_11	277	0.1143
Cropland_7	485	0.0169		Pasture_1	336	0.0864
Cropland_8	412	0.051		Pasture_2	420	0.0473
Cropland_9	392	0.0604		Pasture_3	470	0.0238
Cropland_10	388	0.0622		Pasture_4	406	0.0541
Cropland_11	274	0.1152		Pasture_5	405	0.0544
Forest_1	267	0.1186		Pasture_6	402	0.0558
Forest_2	394	0.0595		Pasture_7	436	0.0397
Forest_3	414	0.0499		Pasture_8	385	0.0638
Forest_4	350	0.0799		Pasture_9	393	0.0601
Forest_5	357	0.0766		Pasture_10	379	0.0667
Forest_6	392	0.0606		Pasture_11	263	0.1204
Forest_7	461	0.0281		Hay_1	336	0.0864
Forest_8	297	0.1046		Hay_2	420	0.0473
Forest_9	292	0.1073		Hay_3	470	0.0238
Forest_10	222	0.1396		Hay_4	406	0.0541
Forest_11	223	0.1394		Hay_5	405	0.0544
HDR_2	420	0.0472		Hay_6	402	0.0558
HDR_3	508	0.0062		Hay_7	436	0.0397
		0.0233		Hay_8	385	0.0638
		0.0091		Hay_9	393	0.0601
		0.0259		Hay_10	379	0.0667
		0.0138		Hay_11	263	0.1204

Table E2. PWAT-PARM4 parameter that varies by land use for Beaver Creek.

Landuse	NSUR
Forest	0.35
Cropland	0.25
Pasture/hay	0.25
LDR	0.2
HDR	0.2

Table E3. CEPSC (monthly interception storage capacity, inches) for Beaver Creek

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.06	0.06	0.06	0.1	0.16	0.16	0.16	0.16	0.16	0.1	0.06	0.06
Cropland	0.06	0.06	0.065	0.078	0.095	0.098	0.098	0.094	0.095	0.077	0.072	0.067
Pasture/Hay	0.06	0.06	0.065	0.078	0.095	0.098	0.098	0.094	0.095	0.077	0.072	0.067
LDR	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HDR	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table E4. UZSN (monthly upper zone storage, inches) for Beaver Creek

Landuse	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.8	0.8	0.8	0.8	0.9	0.99	0.99	0.99	0.9	0.85	0.8	0.8
Cropland	0.25	0.25	0.25	0.3	0.4	0.8	0.8	0.8	0.7	0.5	0.3	0.25
Pasture/Hay	0.7	0.7	0.7	0.7	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.7
Low Density Residential	0.7	0.7	0.7	0.7	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.7
High Density Residential	0.7	0.7	0.7	0.7	0.8	0.9	0.9	0.9	0.8	0.7	0.7	0.7

Table E5. LZETP (monthly lower zone evapotranspiration factor) for Beaver Creek

Landuse	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Forest	0.3	0.3	0.3	0.4	0.7	0.7	0.7	0.7	0.6	0.5	0.4	0.3
Cropland	0.1	0.1	0.1	0.1	0.25	0.55	0.65	0.65	0.55	0.25	0.15	0.1
Pasture/hay	0.15	0.15	0.15	0.25	0.25	0.25	0.25	0.25	0.2	0.2	0.15	0.15
Low Density Residential	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2
High Density Residential	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.2	0.2

Table E6. ACQOP (monthly accumulation rate for fecal coliform) for Beaver Creek

*** BVR-1												
Cropland	1.10E+08	1.10E+09	4.60E+09	3.80E+09	9.80E+08	7.30E+07	7.30E+07	7.30E+07	1.10E+08	1.50E+09	1.50E+09	1.10E+08
Hay	1.10E+08	6.30E+08	2.40E+09	2.00E+09	5.50E+08	5.60E+08	5.50E+08	5.50E+08	1.10E+09	1.10E+09	1.10E+09	1.10E+08
Pasture	1.60E+10	1.80E+10	3.10E+10	3.20E+10	3.20E+10	3.30E+10	3.30E+10	3.40E+10	3.50E+10	2.20E+10	2.40E+10	1.50E+10
Forest	1.10E+08	1.10E+08	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	7.50E+07	1.10E+08	1.10E+08	1.10E+08	1.10E+08
*** BVR-2												
Cropland	4.00E+07	1.60E+09	7.20E+09	6.00E+09	1.50E+09	3.30E+07	3.30E+07	3.30E+07	4.00E+07	1.80E+09	2.30E+09	4.00E+07
Hay	4.90E+07	7.10E+08	3.10E+09	2.50E+09	6.50E+08	6.70E+08	6.50E+08	6.50E+08	1.30E+09	1.30E+09	1.30E+09	4.90E+07
Pasture	1.60E+10	1.70E+10	3.20E+10	3.40E+10	3.40E+10	3.50E+10	3.50E+10	3.50E+10	3.50E+10	2.90E+10	2.80E+10	1.50E+10
Low Density Residential	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09	7.60E+09
High Density Residential	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Forest	4.20E+07	4.20E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	3.50E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07
*** BVR-3												
Cropland	1.80E+07	1.20E+09	5.40E+09	4.40E+09	1.10E+09	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.50E+09	1.70E+09	1.80E+07
Hay	2.10E+07	8.80E+08	3.90E+09	3.20E+09	8.00E+08	8.30E+08	8.00E+08	8.00E+08	1.60E+09	1.60E+09	1.60E+09	2.10E+07
Pasture	1.60E+10	1.80E+10	3.40E+10	3.60E+10	3.40E+10	3.50E+10	3.50E+10	3.50E+10	3.60E+10	2.80E+10	2.80E+10	1.50E+10
Low Density Residential	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09	4.10E+09
High Density Residential	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Forest	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07
*** BVR-4												
Cropland	3.90E+07	1.00E+09	4.40E+09	3.60E+09	9.00E+08	3.10E+07	3.10E+07	3.10E+07	3.90E+07	1.20E+09	1.40E+09	3.90E+07
Hay	3.90E+07	5.40E+08	2.30E+09	1.90E+09	4.90E+08	5.00E+08	4.90E+08	4.90E+08	9.90E+08	9.60E+08	9.90E+08	3.90E+07
Pasture	1.20E+10	1.40E+10	2.30E+10	2.40E+10	2.40E+10	2.50E+10	2.50E+10	2.50E+10	2.60E+10	1.60E+10	1.80E+10	1.10E+10
Low Density Residential	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09	8.00E+09
Forest	4.10E+07	4.10E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	3.30E+07	4.10E+07	4.10E+07	4.10E+07	4.10E+07
*** BVR-5												
Cropland	4.00E+07	5.50E+08	2.40E+09	2.00E+09	5.00E+08	3.40E+07	3.40E+07	3.40E+07	4.00E+07	7.40E+08	7.70E+08	4.00E+07
Hay	4.30E+07	4.00E+08	1.70E+09	1.40E+09	3.60E+08	3.70E+08	3.60E+08	3.60E+08	7.10E+08	6.90E+08	7.10E+08	4.30E+07
Pasture	2.50E+10	2.80E+10	4.90E+10	5.00E+10	5.00E+10	5.10E+10	5.20E+10	5.20E+10	5.40E+10	3.40E+10	3.70E+10	2.30E+10
Forest	4.20E+07	4.20E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	3.60E+07	4.20E+07	4.20E+07	4.20E+07	4.20E+07

** BVR-6												
Cropland	3.00E+07	9.70E+08	4.30E+09	3.50E+09	8.70E+08	1.60E+07	1.60E+07	1.60E+07	3.00E+07	1.10E+09	1.40E+09	3.00E+07
Hay	3.00E+07	5.30E+08	2.30E+09	1.90E+09	4.70E+08	4.90E+08	4.70E+08	4.70E+08	9.80E+08	9.50E+08	9.80E+08	3.00E+07
Pasture	4.30E+08	4.80E+08	8.10E+08	8.20E+08	8.30E+08	8.50E+08	8.60E+08	8.70E+08	9.00E+08	5.80E+08	6.20E+08	4.10E+08
Forest	3.20E+07	3.20E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	1.80E+07	3.20E+07	3.20E+07	3.20E+07	3.20E+07
*** BVR-7												
Cropland	9.20E+07	1.10E+09	4.80E+09	4.00E+09	1.00E+09	6.50E+07	6.50E+07	6.50E+07	9.20E+07	8.10E+08	1.60E+09	9.20E+07
Hay	9.20E+07	4.40E+08	1.70E+09	1.40E+09	3.80E+08	7.20E+08	6.50E+07	3.80E+08	1.10E+09	4.10E+08	7.50E+08	9.20E+07
Pasture	1.40E+11	1.40E+11	2.70E+11	3.00E+11	2.90E+11	2.90E+11	2.90E+11	2.90E+11	3.00E+11	2.80E+11	2.60E+11	1.30E+11
Low Density Residential	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09	3.20E+09
Forest	9.20E+07	9.20E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	6.50E+07	9.20E+07	9.20E+07	9.20E+07	9.20E+07
*** BVR-8												
Cropland	1.80E+07	1.70E+09	7.60E+09	6.30E+09	1.50E+09	1.70E+07	1.70E+07	1.70E+07	1.80E+07	2.30E+09	2.40E+09	1.80E+07
Hay	2.40E+07	7.50E+08	3.30E+09	2.80E+09	6.80E+08	7.00E+08	6.80E+08	6.80E+08	1.40E+09	1.30E+09	1.40E+09	2.40E+07
Pasture	1.80E+10	2.00E+10	3.50E+10	3.50E+10	3.60E+10	3.70E+10	3.70E+10	3.80E+10	3.80E+10	2.40E+10	2.60E+10	1.70E+10
Forest	2.00E+07	2.00E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	2.00E+07	2.00E+07	2.00E+07	2.00E+07
*** BVR-9												
Cropland	4.40E+07	5.50E+08	2.40E+09	2.00E+09	5.00E+08	3.70E+07	3.70E+07	3.70E+07	4.40E+07	7.50E+08	7.70E+08	4.40E+07
Hay	6.40E+07	4.20E+08	1.70E+09	1.40E+09	3.80E+08	3.90E+08	3.80E+08	3.80E+08	7.30E+08	7.10E+08	7.30E+08	6.40E+07
Pasture	4.70E+10	5.00E+10	6.50E+10	6.50E+10	6.50E+10	6.50E+10	6.60E+10	6.60E+10	6.80E+10	5.40E+10	5.60E+10	4.60E+10
Low Density Residential	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11	2.30E+11
Forest	4.50E+07	4.50E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	3.80E+07	4.50E+07	4.50E+07	4.50E+07	4.50E+07
*** BVR-10												
Cropland	1.70E+07	1.10E+09	4.70E+09	3.90E+09	9.60E+08	1.70E+07	1.70E+07	1.70E+07	1.70E+07	7.40E+08	1.50E+09	1.70E+07
Hay	3.30E+07	5.10E+08	2.20E+09	1.80E+09	4.60E+08	6.00E+08	3.40E+08	4.60E+08	1.00E+09	7.70E+08	9.20E+08	3.30E+07
Pasture	3.50E+10	3.70E+10	7.00E+10	7.50E+10	7.50E+10	7.60E+10	7.60E+10	7.70E+10	7.80E+10	6.40E+10	6.20E+10	3.40E+10
Forest	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07	1.90E+07
*** BVR-11												
Cropland	2.80E+07	1.00E+09	4.60E+09	3.80E+09	9.30E+08	2.40E+07	2.40E+07	2.40E+07	2.80E+07	1.40E+09	1.50E+09	2.80E+07
Hay	2.80E+07	5.40E+08	2.30E+09	1.90E+09	4.90E+08	5.00E+08	4.90E+08	4.90E+08	9.90E+08	9.60E+08	9.90E+08	2.80E+07
Pasture	1.90E+10	2.20E+10	3.80E+10	3.80E+10	3.90E+10	4.00E+10	4.00E+10	4.10E+10	4.10E+10	2.60E+10	2.80E+10	1.80E+10
Low Density Residential	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08
Forest	2.90E+07	2.90E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.50E+07	2.90E+07	2.90E+07	2.90E+07	2.90E+07

Table E7. SQOLIM (monthly asymptotic limit on surface accumulation) for Beaver Creek

*** BVR-1												
Cropland	9.70E+08	9.90E+09	4.20E+10	3.40E+10	8.80E+09	6.60E+08	6.60E+08	6.60E+08	9.70E+08	1.30E+10	1.40E+10	9.70E+08
Hay	9.70E+08	5.70E+09	2.20E+10	1.80E+10	4.90E+09	5.10E+09	4.90E+09	4.90E+09	9.80E+09	9.50E+09	9.80E+09	9.70E+08
Pasture	1.40E+11	1.60E+11	2.80E+11	2.90E+11	2.90E+11	3.00E+11	3.00E+11	3.10E+11	3.10E+11	2.00E+11	2.10E+11	1.40E+11
Forest	9.80E+08	9.80E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	6.70E+08	9.80E+08	9.80E+08	9.80E+08	9.80E+08
*** BVR-2												
Cropland	3.60E+08	1.50E+10	6.50E+10	5.40E+10	1.30E+10	3.00E+08	3.00E+08	3.00E+08	3.60E+08	1.60E+10	2.10E+10	3.60E+08
Hay	4.40E+08	6.40E+09	2.80E+10	2.30E+10	5.80E+09	6.00E+09	5.80E+09	5.80E+09	1.20E+10	1.10E+10	1.20E+10	4.40E+08
Pasture	1.40E+11	1.50E+11	2.90E+11	3.10E+11	3.10E+11	3.10E+11	3.10E+11	3.20E+11	3.20E+11	2.60E+11	2.50E+11	1.40E+11
Low Density Residential	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10	6.80E+10
High Density Residential	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Forest	3.80E+08	3.80E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.20E+08	3.80E+08	3.80E+08	3.80E+08	3.80E+08
*** BVR-3												
Cropland	1.60E+08	1.10E+10	4.80E+10	4.00E+10	9.80E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.30E+10	1.50E+10	1.60E+08
Hay	1.90E+08	7.90E+09	3.50E+10	2.90E+10	7.20E+09	7.40E+09	7.20E+09	7.20E+09	1.50E+10	1.40E+10	1.50E+10	1.90E+08
Pasture	1.40E+11	1.60E+11	3.10E+11	3.20E+11	3.10E+11	3.10E+11	3.20E+11	3.20E+11	3.30E+11	2.50E+11	2.50E+11	1.40E+11
Low Density Residential	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10	3.60E+10
High Density Residential	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.00E-01
Forest	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
*** BVR-4												
Cropland	3.50E+08	9.00E+09	4.00E+10	3.30E+10	8.10E+09	2.80E+08	2.80E+08	2.80E+08	3.50E+08	1.10E+10	1.30E+10	3.50E+08
Hay	3.50E+08	4.90E+09	2.10E+10	1.70E+10	4.40E+09	4.50E+09	4.40E+09	4.40E+09	8.90E+09	8.60E+09	8.90E+09	3.50E+08
Pasture	1.10E+11	1.20E+11	2.10E+11	2.10E+11	2.20E+11	2.20E+11	2.20E+11	2.30E+11	2.30E+11	1.50E+11	1.60E+11	1.00E+11
Low Density Residential	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10	7.20E+10
Forest	3.70E+08	3.70E+08	2.90E+08	2.90E+08	2.90E+08	2.90E+08	2.90E+08	2.90E+08	3.70E+08	3.70E+08	3.70E+08	3.70E+08
*** BVR-5												
Cropland	3.60E+08	4.90E+09	2.10E+10	1.80E+10	4.50E+09	3.10E+08	3.10E+08	3.10E+08	3.60E+08	6.70E+09	6.90E+09	3.60E+08
Hay	3.90E+08	3.60E+09	1.50E+10	1.20E+10	3.30E+09	3.30E+09	3.30E+09	3.30E+09	6.40E+09	6.20E+09	6.40E+09	3.90E+08
Pasture	2.20E+11	2.50E+11	4.40E+11	4.50E+11	4.50E+11	4.60E+11	4.60E+11	4.70E+11	4.80E+11	3.10E+11	3.30E+11	2.10E+11
Forest	3.70E+08	3.70E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.30E+08	3.70E+08	3.70E+08	3.70E+08	3.70E+08

*** BVR-6												
Cropland	2.70E+08	8.70E+09	3.90E+10	3.20E+10	7.80E+09	1.40E+08	1.40E+08	1.40E+08	2.70E+08	9.80E+09	1.20E+10	2.70E+08
Hay	2.70E+08	4.80E+09	2.10E+10	1.70E+10	4.30E+09	4.40E+09	4.30E+09	4.30E+09	8.80E+09	8.50E+09	8.80E+09	2.70E+08
Pasture	3.90E+09	4.40E+09	7.30E+09	7.40E+09	7.50E+09	7.60E+09	7.70E+09	7.80E+09	8.10E+09	5.20E+09	5.60E+09	3.70E+09
Forest	2.80E+08	2.80E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	1.60E+08	2.80E+08	2.80E+08	2.80E+08	2.80E+08
*** BVR-7												
Cropland	8.30E+08	1.00E+10	4.30E+10	3.60E+10	9.10E+09	5.80E+08	5.80E+08	5.80E+08	8.30E+08	7.30E+09	1.40E+10	8.30E+08
Hay	8.30E+08	4.00E+09	1.50E+10	1.20E+10	3.50E+09	6.50E+09	5.80E+08	3.50E+09	9.70E+09	3.70E+09	6.80E+09	8.30E+08
Pasture	1.20E+12	1.20E+12	2.50E+12	2.70E+12	2.60E+12	2.60E+12	2.60E+12	2.60E+12	2.70E+12	2.60E+12	2.40E+12	1.20E+12
Low Density Residential	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10	2.90E+10
Forest	8.30E+08	8.30E+08	5.80E+08	5.80E+08	5.80E+08	5.80E+08	5.80E+08	5.80E+08	8.30E+08	8.30E+08	8.30E+08	8.30E+08
*** BVR-8												
Cropland	1.60E+08	1.50E+10	6.80E+10	5.60E+10	1.40E+10	1.50E+08	1.50E+08	1.50E+08	1.60E+08	2.10E+10	2.20E+10	1.60E+08
Hay	2.10E+08	6.70E+09	3.00E+10	2.50E+10	6.10E+09	6.30E+09	6.10E+09	6.10E+09	1.20E+10	1.20E+10	1.20E+10	2.10E+08
Pasture	1.60E+11	1.80E+11	3.10E+11	3.20E+11	3.20E+11	3.30E+11	3.30E+11	3.40E+11	3.40E+11	2.20E+11	2.30E+11	1.50E+11
Forest	1.80E+08	1.80E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.80E+08	1.80E+08	1.80E+08	1.80E+08
*** BVR-9												
Cropland	3.90E+08	5.00E+09	2.10E+10	1.80E+10	4.50E+09	3.30E+08	3.30E+08	3.30E+08	3.90E+08	6.70E+09	7.00E+09	3.90E+08
Hay	5.80E+08	3.80E+09	1.50E+10	1.30E+10	3.40E+09	3.50E+09	3.40E+09	3.40E+09	6.60E+09	6.40E+09	6.60E+09	5.80E+08
Pasture	4.20E+11	4.50E+11	5.90E+11	5.90E+11	5.90E+11	5.90E+11	5.90E+11	6.00E+11	6.10E+11	4.90E+11	5.00E+11	4.10E+11
Low Density Residential	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12	2.10E+12
Forest	4.10E+08	4.10E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	3.40E+08	4.10E+08	4.10E+08	4.10E+08	4.10E+08
*** BVR-10												
Cropland	1.60E+08	9.50E+09	4.30E+10	3.50E+10	8.60E+09	1.60E+08	1.60E+08	1.60E+08	1.60E+08	6.60E+09	1.40E+10	1.60E+08
Hay	3.00E+08	4.50E+09	2.00E+10	1.60E+10	4.20E+09	5.40E+09	3.10E+09	4.20E+09	9.40E+09	7.00E+09	8.30E+09	3.00E+08
Pasture	3.10E+11	3.30E+11	6.30E+11	6.70E+11	6.80E+11	6.80E+11	6.90E+11	6.90E+11	7.00E+11	5.70E+11	5.50E+11	3.00E+11
Forest	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08	1.70E+08
*** BVR-11												
Cropland	2.50E+08	9.20E+09	4.10E+10	3.40E+10	8.40E+09	2.20E+08	2.20E+08	2.20E+08	2.50E+08	1.30E+10	1.30E+10	2.50E+08
Hay	2.50E+08	4.80E+09	2.10E+10	1.80E+10	4.40E+09	4.50E+09	4.40E+09	4.40E+09	8.90E+09	8.60E+09	8.90E+09	2.50E+08
Pasture	1.70E+11	1.90E+11	3.40E+11	3.40E+11	3.50E+11	3.60E+11	3.60E+11	3.70E+11	3.70E+11	2.40E+11	2.50E+11	1.60E+11
Low Density Residential	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09	1.40E+09
Forest	2.60E+08	2.60E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.30E+08	2.60E+08	2.60E+08	2.60E+08	2.60E+08

APPENDIX F.
Fecal Coliform Loading in Sub-Watersheds

Table F-1. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-1.

Month	Fecal Coliform loadings (x10^{10} cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	0	4	374	10	0
Feb.	1	24	387	10	0
Mar.	6	102	741	7	0
Apr.	5	82	727	7	0
May.	1	23	757	7	0
Jun.	0	23	742	7	0
Jul.	0	23	779	7	0
Aug.	0	23	792	7	0
Sep.	0	44	783	10	0
Oct.	2	44	515	10	0
Nov.	2	44	534	10	0
Dec.	0	4	352	10	0
Total	17	439	7,483	104	0

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-2. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-2.

Month	Fecal Coliform loadings (x10^{10} cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	17	115	21,374	43	492
Feb.	505	1,559	20,897	39	448
Mar.	2,459	7,368	44,072	35	492
Apr.	1,970	5,911	45,355	34	476
May.	503	1,552	46,865	35	492
Jun.	13	1,549	45,630	34	476
Jul.	14	1,552	47,513	35	492
Aug.	14	1,552	47,880	35	492
Sep.	16	3,019	46,900	41	476
Oct.	568	3,023	39,653	43	492
Nov.	761	3,019	37,005	41	476
Dec.	17	115	20,712	43	492
Total	6,857	30,332	463,855	461	5,791

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-3. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-3.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	7	29	12,407	15	483
Feb.	364	972	12,652	14	440
Mar.	1,797	4,755	26,678	15	483
Apr.	1,439	3,809	26,679	14	467
May.	365	974	26,705	15	483
Jun.	6	973	26,123	14	467
Jul.	7	974	27,257	15	483
Aug.	7	974	27,534	15	483
Sep.	6	1,918	27,288	14	467
Oct.	481	1,919	21,545	15	483
Nov.	551	1,918	20,775	14	467
Dec.	7	29	11,910	15	483
Total	5,037	19,244	267,553	175	5,691

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-4. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-4.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	4	31	5,593	19	54
Feb.	100	414	5,789	18	49
Mar.	483	1,950	11,148	16	54
Apr.	387	1,564	10,930	15	52
May.	99	410	11,349	16	54
Jun.	3	409	11,126	15	52
Jul.	4	410	11,679	16	54
Aug.	4	410	11,862	16	54
Sep.	4	800	11,737	19	52
Oct.	133	801	7,724	19	54
Nov.	150	800	8,014	19	52
Dec.	4	31	5,262	19	54
Total	1,376	8,031	112,213	207	636

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-5. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-5.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	6	29	9,370	11	71
Feb.	49	168	9,691	10	65
Mar.	222	735	18,649	10	71
Apr.	179	592	18,294	10	69
May.	48	167	19,027	10	71
Jun.	5	166	18,657	10	69
Jul.	5	167	19,584	10	71
Aug.	5	167	19,892	10	71
Sep.	5	311	19,664	11	69
Oct.	72	312	12,928	11	71
Nov.	72	311	13,415	11	69
Dec.	6	29	8,815	11	71
Total	672	3,155	187,985	124	839

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-6. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-6.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	1	8	67	3	45
Feb.	27	134	81	2	41
Mar.	133	639	187	1	45
Apr.	107	512	172	1	44
May.	27	131	141	1	45
Jun.	1	131	138	1	44
Jul.	1	131	145	1	45
Aug.	1	131	147	1	45
Sep.	1	261	159	3	44
Oct.	33	262	115	3	45
Nov.	41	261	118	3	44
Dec.	1	8	63	3	45
Total	374	2,609	1,532	24	532

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-7. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-7.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	**Hay**	**Pasture**	**Forest**	**Residential[1]**
Jan.	4	9	7,739	0	1
Feb.	42	40	7,186	0	1
Mar.	197	165	15,631	0	1
Apr.	158	133	16,376	0	1
May.	42	38	16,864	0	1
Jun.	3	70	16,243	0	1
Jul.	3	6	16,779	0	1
Aug.	3	38	16,830	0	1
Sep.	4	104	16,485	0	1
Oct.	33	41	16,247	0	1
Nov.	63	72	14,603	0	1
Dec.	4	9	7,680	0	1
Total	555	725	168,663	3	16

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-8. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-8.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	**Hay**	**Pasture**	**Forest**	**Residential[1]**
Jan.	0	21	9,000	16	69
Feb.	28	553	9,297	15	63
Mar.	136	2,691	17,867	16	69
Apr.	109	2,156	17,542	15	67
May.	28	554	18,291	16	69
Jun.	0	554	17,981	15	67
Jul.	0	554	18,875	16	69
Aug.	0	554	19,171	16	69
Sep.	0	1,088	18,892	16	67
Oct.	42	1,089	12,404	16	69
Nov.	42	1,088	12,868	16	67
Dec.	0	21	8,466	16	69
Total	387	10,924	180,655	189	813

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-9. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-9.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	1	13	5,469	131	450
Feb.	5	55	5,240	120	411
Mar.	23	228	7,511	111	450
Apr.	19	184	7,313	108	436
May.	5	55	7,559	111	450
Jun.	1	54	7,330	108	436
Jul.	1	55	7,639	111	450
Aug.	1	55	7,705	111	450
Sep.	1	99	7,592	127	436
Oct.	7	100	6,248	131	450
Nov.	7	99	6,247	127	436
Dec.	1	13	5,348	131	450
Total	70	1,010	81,201	1,429	5,308

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-10. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-10.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	0	7	4,280	47	44
Feb.	18	100	4,165	43	40
Mar.	88	473	8,677	47	44
Apr.	70	379	8,907	45	43
May.	18	100	9,242	47	44
Jun.	0	125	9,007	45	43
Jul.	0	75	9,379	47	44
Aug.	0	100	9,450	47	44
Sep.	0	218	9,232	45	43
Oct.	14	168	7,823	47	44
Nov.	27	193	7,330	45	43
Dec.	0	7	4,151	47	44
Total	237	1,945	91,642	553	521

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

Table F-11. Monthly nonpoint fecal coliform loadings in sub-watershed BVR-11.

Month	Fecal Coliform loadings ($x10^{10}$ cfu/month)				
	Cropland	Hay	Pasture	Forest	Residential[1]
Jan.	0	2	621	295	8
Feb.	4	28	641	268	8
Mar.	18	136	1,231	260	8
Apr.	15	109	1,209	251	8
May.	4	28	1,261	260	8
Jun.	0	28	1,240	251	8
Jul.	0	28	1,302	260	8
Aug.	0	28	1,323	260	8
Sep.	0	55	1,303	285	8
Oct.	6	56	855	295	8
Nov.	6	55	887	285	8
Dec.	0	2	584	295	8
Total	53	557	12,458	3,263	99

[1]Includes Farmstead, Low Density Residential, and High Density Residential Loads

APPENDIX G.
Required Reductions in Fecal Coliform Loads by Sub-Watershed – Allocation Scenario

Table G-1a. Required annual reductions in nonpoint sources in sub-watershed BVR-1.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	1,714	0.2%	1,200	30%
Pasture/Hay	792,218	98%	0	100%
Forest	10,357	1%	10,357	0%
Residential	0	0%	0	0%
Total	804,290	100%	11,557	99%

Table G-1b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-1.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	1,804	27%	1,804	0%
Wildlife in Streams	4,787	73%	4,787	0%
Straight Pipes	0	0%	0	100%
Total	6,592	100%	6,592	0%

Table G-2a. Required annual reductions in nonpoint sources in sub-watershed BVR-2.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	685,679	1%	479,975	30%
Pasture/Hay	49,418,752	97%	0	100%
Forest	46,075	0.1%	46,075	0%
Residential	579,104	1%	579,104	0%
Total	50,729,610	100%	1,105,154	98%

Table G-2b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-2.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	73,602	65%	73,602	0%
Wildlife in Streams	39,674	35%	39,674	0%
Straight Pipes	0	0%	0	100%
Total	113,277	100%	113,277	0%

Table G-3a. Required annual reductions in nonpoint sources in sub-watershed BVR-3.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	503,680	2%	352,576	30%
Pasture/Hay	28,679,749	96%	0	100%
Forest	17,542	0.1%	17,542	0%
Residential	569,060	2%	569,060	0%
Total	29,770,031	100%	939,178	97%

Table G-3b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-3.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	0	0%	0	0%
Wildlife in Streams	904	4%	904	0%
Straight Pipes	20,892	96%	0	100%
Total	21,796	100%	904	96%

Table G-4a. Required annual reductions in nonpoint sources in sub-watershed BVR-4.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	137,637	1%	96,346	30%
Pasture/Hay	12,024,380	98%	0	100%
Forest	20,701	0.2%	20,701	0%
Residential	63,554	0.5%	63,554	0%
Total	12,246,271	100%	180,601	99%

Table G-4b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-4.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	31,987	71%	31,987	0%
Wildlife in Streams	13,053	29%	13,053	0%
Straight Pipes	0	0%	0	100%
Total	45,040	100%	45,040	0%

Table G-5a. Required annual reductions in nonpoint sources in sub-watershed BVR-5.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	67,211	0.3%	0	100%
Pasture/Hay	19,113,990	99%	0	100%
Forest	12,444	0.1%	12,444	0%
Residential	83,934	0.4%	0	100%
Total	19,277,579	100%	12,444	100%

Table G-5b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-5.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	49,539	81%	0	100%
Wildlife in Streams	11,459	19%	5,729	50%
Straight Pipes	0	0%	0	100%
Total	60,997	100%	5,729	91%

Table G-6a. Required annual reductions in nonpoint sources in sub-watershed BVR-6.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	37,383	7%	0	100%
Pasture/Hay	414,056	82%	0	100%
Forest	2,431	0.5%	2,431	0%
Residential	53,217	10%	0	100%
Total	507,086	100%	2,431	100%

Table G-6b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-6.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	109	6%	0	100%
Wildlife in Streams	1,593	94%	797	50%
Straight Pipes	0	0%	0	100%
Total	1,703	100%	797	53%

Table G-7a. Required annual reductions in nonpoint sources in sub-watershed BVR-7.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	55,463	0.3%	0	100%
Pasture/Hay	16,938,818	100%	0	100%
Forest	315	0%	315	0%
Residential	1,644	0%	0	100%
Total	16,996,240	100%	315	100%

Table G-7b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-7.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	113,707	96%	0	100%
Wildlife in Streams	4,850	4%	2,425	50%
Straight Pipes	0	0%	0	100%
Total	118,557	100%	2,425	98%

Table G-8a. Required annual reductions in nonpoint sources in sub-watershed BVR-8.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	38,672	0.2%	0	100%
Pasture/Hay	19,157,919	99%	0	100%
Forest	18,938	0.1%	18,938	0%
Residential	81,305	0.4%	0	100%
Total	19,296,834	100%	18,938	100%

Table G-8b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-8.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	7,928	27%	0	100%
Wildlife in Streams	1,004	3%	502	50%
Straight Pipes	20,527	70%	0	100%
Total	29,460	100%	502	98%

Table G-9a. Required annual reductions in nonpoint sources in sub-watershed BVR-9.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	7,014	0.1%	0	100%
Pasture/Hay	8,221,164	92%	0	100%
Forest	142,940	2%	142,940	0%
Residential	530,767	6%	0	100%
Total	8,901,884	100%	142,940	98%

Table G-9b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-9.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	45,110	54%	0	100%
Wildlife in Streams	30,542	37%	15,271	50%
Straight Pipes	7,305	9%	0	100%
Total	82,957	100%	15,271	82%

Table G-10a. Required annual reductions in nonpoint sources in sub-watershed BVR-10.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	23,686	0.2%	0	100%
Pasture/Hay	9,358,716	99%	0	100%
Forest	55,262	0.6%	55,262	0%
Residential	52,121	0.5%	0	100%
Total	9,489,785	100%	55,262	99%

Table G-10b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-10.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	5,827	85%	0	100%
Wildlife in Streams	1,014	15%	507	50%
Straight Pipes	0	0%	0	100%
Total	6,841	100%	507	93%

Table G-11a. Required annual reductions in nonpoint sources in sub-watershed BVR-11.

Land Use	Current conditions load (x 10^8 cfu/year)	Percent of total load from nonpoint sources	TMDL nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cropland	5,266	0.3%	0	100%
Pasture/Hay	1,301,444	79%	0	100%
Forest	326,251	20%	326,251	0%
Residential	9,862	0.6%	0	100%
Total	1,642,823	100%	326,251	80%

Table G-11b. Required annual reductions in direct nonpoint sources in sub-watershed BVR-11.

Source	Current Conditions load (x 10^8 cfu/year)	Percent of total load to stream from direct nonpoint sources	TMDL direct nonpoint source allocation load (x 10^8 cfu/year)	Percent Reduction
Cattle in Streams	273	0.7%	0	100%
Wildlife in Streams	38,925	99%	19,463	50%
Straight Pipes	0	0%	0	100%
Total	39,199	100%	19,463	50%

APPENDIX H.
Simulated Stream Flow Chart for TMDL Allocation Period

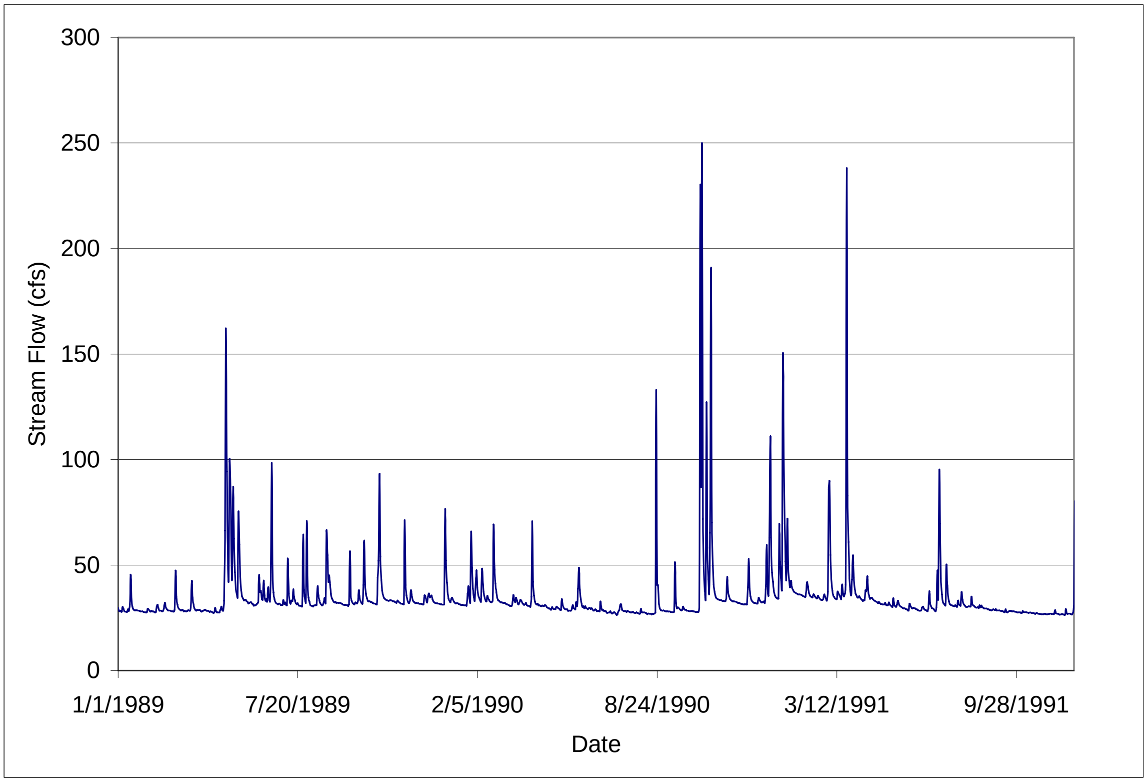

Figure H.1. Simulated Stream Flow for Beaver Creek TMDL Allocation Period.

APPENDIX I.
Observed Fecal Coliform Concentrations and Antecedent Rainfall

Table I.1. Observed fecal coliform concentrations and antecedent rainfall for station 1BBVR003.60 on Beaver Creek.

Date	Fecal Coliform (cfu/100 mL)	Total Rainfall for Sampling Day and Preceding 5 Days (inches)
9/7/1994	300	0.10
9/28/1995	1200	1.00
8/28/1996	1500	0.80
7/21/1997	600	0.80
4/26/1999	300	0.30
8/9/1999	4000	0.02
10/4/1999	4700	1.57
11/9/1999	400	0.00
2/24/2000	100	0.04
4/5/2000	100	0.20
6/26/2000	100	0.66
7/17/2000	200	0.57
9/20/2000	400	1.80
11/30/2000	300	0.40
1/23/2001	100	1.40
3/29/2001	100	1.20
6/4/2001	900	0.40
8/6/2001	400	0.02
10/30/2001	3000	0.00
12/12/2001	6800	1.24
2/28/2002	100	0.00
4/15/2002	600	0.50
6/27/2002	1200	0.10
7/24/2002	8000	2.00
10/3/2002	8000	0.10
12/12/2002	200	0.90
2/6/2003	100	0.50
4/3/2003	100	0.90
6/2/2003	300	0.60

APPENDIX J.
CAFOs in the Beaver Creek Watershed

Table J.1. Permitted Poultry CAFOs in Beaver Creek.

Permit Number	Bird Type	Sub - watershed
VPG260361	Broiler	BVR-08
VPG260079	Broiler	BVR-03
VPG260633	Turkey	BVR-03
VPG260661	Turkey	BVR-03
VPG260065	Pullets	BVR-03
VPG260354	Turkey	BVR-03
VPG260076	Broiler	BVR-03
VPG260038	Turkey	BVR-03
VPG260040	Broiler	BVR-02
VPG260621	Broiler	BVR-02
VPG260257	Broiler	BVR-02
VPG260277	Broiler	BVR-02
VPG260761	Pullets	BVR-08
VPG260125	Turkey Hens	BVR-07
VPG260226	Turkey Hens	BVR-05
VPG260543	Turkey Hens	BVR-09

APPENDIX K.
Scenarios for Fivefold Increase in Permitted Discharge Flows

To allow for future growth, scenarios were created for Beaver Creek in which the point source flows were increased by a factor of 5, while retaining the 200 cfu/100 mL limit on bacteria. This effectively increased the WLA by a factor of 5. Figure K.1 displays the results. The TMDL equations that would represent these situations are included in Table K.1.

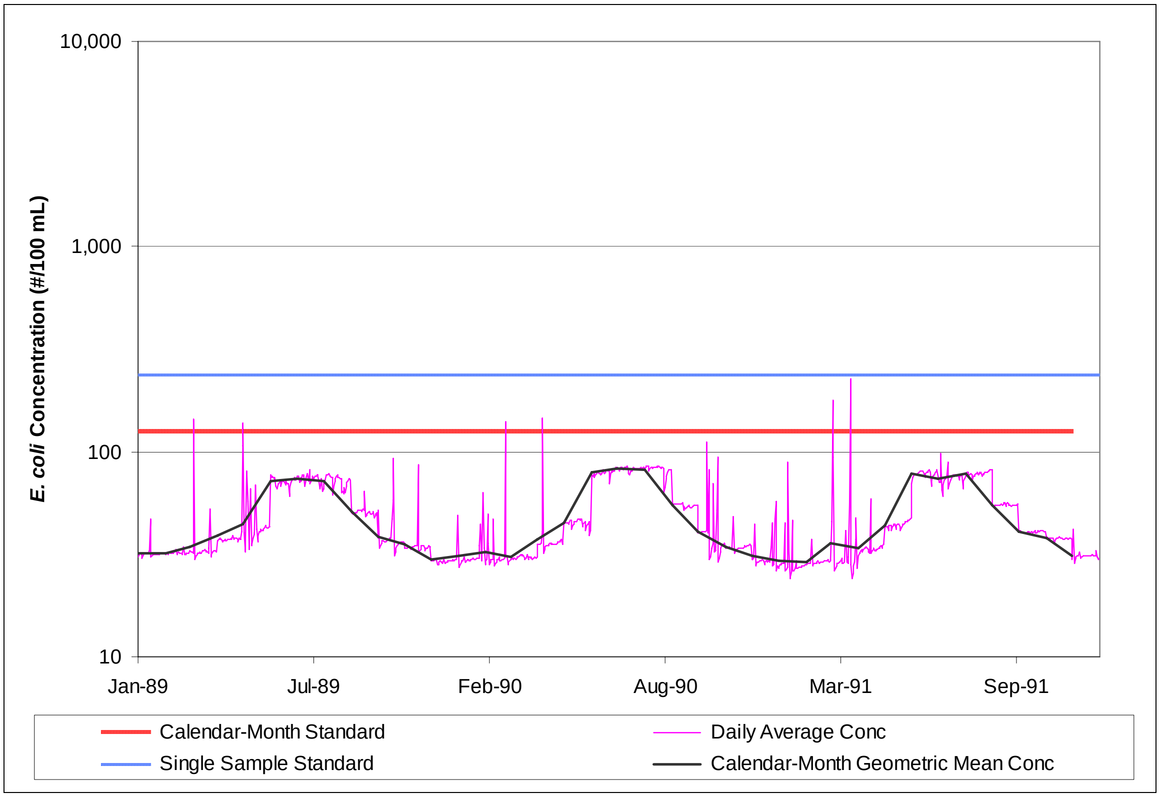

Figure K.1. Daily average and calendar-month geometric mean *E. coli* concentration at the Beaver Creek watershed outlet under the fivefold WLA increase scenario.

Table K.1. Average annual *E. coli* loadings (cfu/year) at the watershed outlet for Beaver Creek under the fivefold WLA increase scenario.

ΣWLA	ΣLA	TMDL
$6.10x10^{10}$	$1,562x10^{10}$	$1,568x10^{10}$

As can be seen from Figure K.1, the new scenario results in no violations of the instantaneous or geometric mean standards. Therefore, it is assumed that future growth in point source dischargers with a consistent permitted bacteria concentration of 200 cfu/100 mL fecal coliform will not cause additional violations of the water quality standards.